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Water Allocation for Future Development in the Uintah Basin

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WATER ALLOCATION FOR FUTURE DEVELOPMENT

IN THE UINTAH BASIN

by

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INTRODUCTION

The proximity and avilability of water has been a primary consideration in the settlement and development of the arid western states. As the number of settlers increased, most readily available sources of potable water were developed. As development continued, the need to develop additional water sources for culinary and agricultural use became more evident. Eventually it became apparent that it was beyond the means of the settlers to develop more water resources. It was feared that this could slow or stop settlement unless more water was developed.

Shortly after the turn of the century the Bureau of Reclamation of the Department of the Interior was charged with furnishing the engineering expertise and other inputs needed to develop the water resources of the West for use by municipalities and especially agriculture. Since that time the Bureau of Reclamation and other groups have served to bring millions of acre feet of water to western farms, ranches and cities. Now the increased population of western communities and pressure to develop the energy resources of the country and particularly the West may cause water to become a developmental constraint once again.

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JUSTIFICATION

Because water is such an important factor in the arid and semi-arid states of the West, much work has been done to assess the physical and economic implications of water on the development of these areas. The Uinta Basin is considered to be one of the water "rich" areas of the state of Utah. This has lead to the idea that instead of allowing the water allocated to this area to leave the state, the Central Utah Project would develop the water of the Basin for use within the state. Much of this water would be used by local agriculture or exported from the Uinta Basin to meet agricultural and municipal needs in other parts of the state. At the time the Central Utah Project was conceived the Uinta Basin was a very sparsely populated area characterized by a net out-migration of people, and agriculture was the main industry.

Since 1970 the out-migration situation has reversed and crude oil production has become a major industry in the area. The introduction of the oil industry has caused some communities to double in size in the last four years. This tremendous population increase combined with the potential increase from other energy development has caused some residents of the basin to wonder if the economy can develop unhindered by a water shortage if the present water export plans materialize.

OBJECTIVES

The major objectives of this study are to determine whether or not future needs for water in the Uinta Basin can be satisfied by the present quantity of water produced by the hydrology of the Basin.

The specific objectives are as follows:

1. To determine the present demand for water in the Basin.
2. To determine the present annual quantity of water produced by the Basin.
3. To project the changes in the demand for water in the Uinta Basin resulting from energy, agricultural and other development.
4. To project the changes in the quantity of water available to satisfy these increased demands as successive units of water are made available.

PROCEDURE

Objective 1: The present demand for water in the Basin will be obtained from secondary sources and delineated to use by economic sector. This use classification will be as follows:

1. Agriculture
2. Household
3. Industry
4. Public Service
5. Recreation
6. Environmental Control
7. Other Uses

County, city, state and federal government water records will give this information. Once the figure for each use is obtained, they can be totaled to give an estimate of the quantity of water demanded at present prices.

Objective 2: Quantity estimates of water produced by the hydrology of the Basin will come from secondary sources grouped by water origin as follows:

1. Surface water sources
2. Subsurface water sources
3. Return flows

Detailed information on water quantity of the area has been prepared by agencies of federal and state governments. These reports give totals and averages for all the streams of the state. The total quantity of water available for use will be obtained from these sources.

Objective 3: The impact on the demand for water in the Basin resulting from the introduction of the extractive, manufacturing and service industries of the area will be analyzed. Secondary sources will provide useful expansion coefficients which will aid in the computation of the population increase resulting from the introduction of each new job in the economic base. As population and industrial expansions are defined, water needs will be based on this information.

Objective 4: If it can be shown that the projected water needs of the area will exceed the present quantity of water available, then attention will need to be focused on ways to augment present sources. More water may be made available by:

1. Increasing surface and subsurface development.
2. Recycling to provide better return flow coefficients.
3. Development of supplemental supplies.
4. Increased efficiency in present uses.
5. Redistribution.

All of these methods will probably increase the cost of water delivery. If so, the benefits of using the water in a more productive use must be compared to the cost of development of the water. The cost of development and/or the quantity available may serve as developmental constraints.

REVIEW OF LITERATURE

There has been considerable work done in the Uinta Basin by the Bureau of Reclamation, the United States Geological Survey (USGS) and other interests. The Bureau of Reclamation has examined the allocation patterns of the study area in conjunction with the Central Utah Project.

The USGS maintains gauging stations on all the major streams of the area. These gauging station records are the most accurate quantity measurements available. Other interest groups have conducted research in the area, but these efforts have mainly been physical inventories and other descriptive data. One of the main descriptive studies is the Master's thesis of Lloyd R. Austin of the Department of Civil Engineering at Utah State University[1]. The study gives a relatively detailed description of the water resources of the study area.

Another important study is the Doctoral dissertation of Alton B. King also of the Department of Civil Engineering at Utah State University[2]. This study describes some of the water problems of the state and derives water supply curves for the hydrologic units of Utah.

Mr. John Keith of the Department of Economics at Utah State University has written a dissertation titled The Economic Efficiency of Interbasin Transfers of Agricultural Water in Utah: A Mathematical

[1]Lloyd R. Austin, Water Management Alternatives in the Uintah Basin, unpublished Master's thesis, Utah State University, 1970.

[2]Alton B. King, Development of Regional Supply Functions and a Least Cost Model for Allocating Water Resources in Utah: A Parametric Linear Programming Approach, unpublished Doctoral dissertation, Utah State University, 1969.

Programming Approach.[3] Mr. Keith's dissertation is a study of the water allocations between hydrologic units throughout the state of Utah. The study con siders demographic changes and compares some allocative methods of providing water to all users in the state. The main thrust of the study was directed at the economic implication of interbasin transfers, including those interbasin transfers in the Uinta Basin area.

The Department of the Interior through the Bureau of Reclamation has also prepared the Final Environmental Statement for the Prototype Oil Shale Leasing Program.[4] This report of several volumes described the areas in Colorado, Utah and Wyoming which have been leased by the federal government for development of oil shale resources. The study describes the areas of potential oil shale development, one of which is in the Uinta Basin, and outlines the environmental effects which could be expected from such an industry. The report also outlines some of the water requirements expected from the industry.

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[3] John Keith, The Economic Efficiency of Interbasin Transfers of Agricultural Water in Utah: A Mathematical Programming Approach, unpublished Doctoral Dissertation, Utah State University, 1972.

[4] U.S. Bureau of Reclamation, Department of Interior, Final Environmental Statement for the Prototype Oil Shale Leasing Program (2400-00785), Vol. 1, Washington D.C., March 1975.

DESCRIPTION OF STUDY AREA

Location

The Uinta Basin is a hydrologic river basin located in the northeast corner of Utah. It includes all of Duchesne, Uintah and Daggett Counties and minor portions of Summit, Wasatch, Carbon, Grand and Emery Counties. The hydrologic area of the Uinta Basin also includes very minor portions of Colorado and Wyoming. The area covered by this study includes Duchesne, Uintah and Daggett Counties. (See Figure 1)

Climate

The Uinta Basin is semi-arid, characterized by low relative humidity and a wide range of daily temperatures. Summer daytime temperatures reach the 80's and 90's and drop to the low 50's at night. Winters are cold with day temperatures in the 20's during January. The mean annual temperature is 45 degrees Fahrenheit.

Growing seasons vary greatly with records showing annual frost free periods of 90 to 218 days. The average growing season is about four months, from late May to late September.

Annual precipation averages about 7 inches at the lower elevations and 15 inches on the higher plateau regions. Records show that about 55 percent of the precipitation falls as rain during the growing season and the remaining 45 percent is winter snow. Most growing season rainfall comes from thunderstorms which are shortlived, but of high intensity. As a result, most of the summer rainfall is lost through rapid runoff and evaporation.

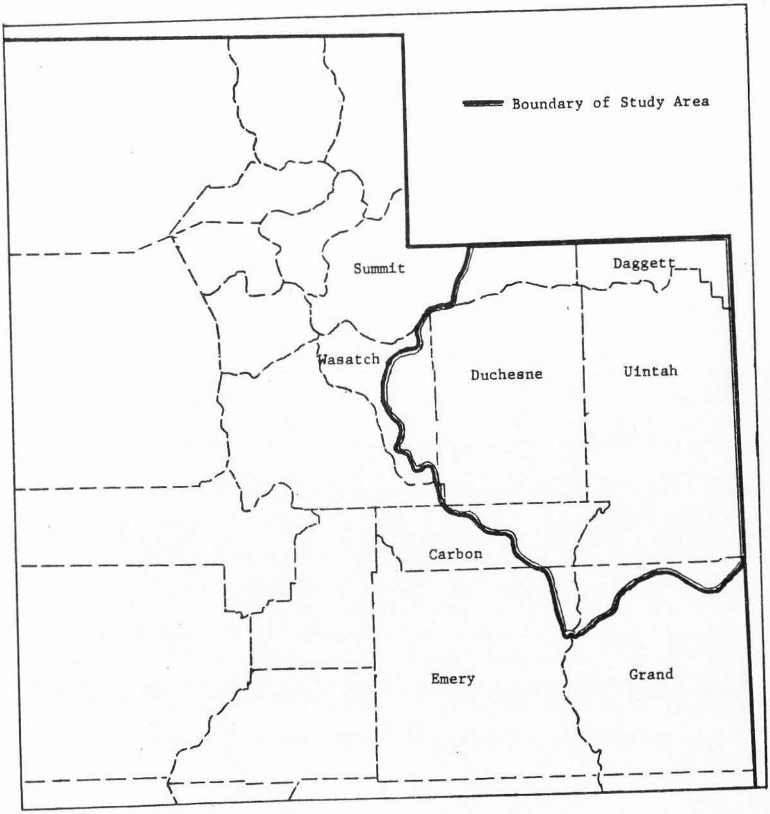

Figure 1. Study area

Snow fall is light, averaging 30 inches per year. However, snow melt in the spring is slow, allowing the soil to absorb most of the moisture.

Winds are irregular and weak except when associated with local thunderstorms. Although there is little wind erosion, winds affect the vegetation of the area by causing moisture to evaporate from the soils before it becomes available for plant use.[1]

Geology

The Uinta Basin is a sedimentary, structural and topographic basin. It is bounded by the Uinta Mountains on the north, the Wasatch Mountains on the west, the cliffs west of Douglas Creek Arch on the east and the Tavaputs Plateau on the south. Elevations of the Basin floor vary from 4,500 feet to more than 8,000 feet. Some elevations in the Uinta Mountains exceed 13,000 feet.

Oil shale of the Green River formation is exposed along the south and east margins of the Basin, and is concealed by younger sediments in the central and northern parts of the Basin. From available drilling information, the thicker, richer oil shale is in the eastern half of the Basin, mostly concealed by younger rocks of the Unita formation. Geologic maps and description of the oil shale in the southeastern part of the Uinta Basin are shown by Cashion's USGS professional paper 548. This paper details the distribution of the rock units, oil shale, gilsonite, bituminous rock, and petroleum in the Green River formation.

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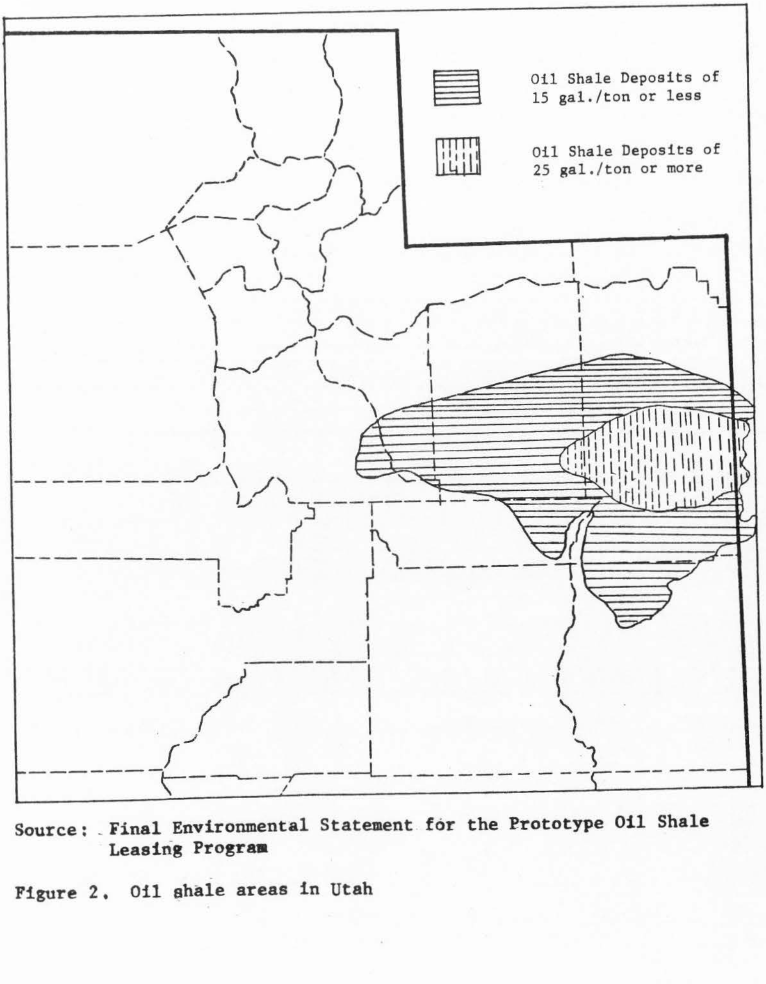
[1] U.S. Bureau of Reclamation, Department of the Interior, Final Environmental Statement for the Prototype Oil Shale Leasing Program (2400-00785), Vol. 1, Washington D.C., March 1973.



Source: Final Environmental Statement for the Prototype Oil Shale Leasing Program

Figure 2. Oil shale areas in Utah

Mineral resources.

Oil shale. Total oil in Uintah Basin shale is estimated to be between 900-1,300 billion barrels. (Present oil consumption in the U.S. is less than 10 billion barrells per year.) The richest Utah oil shale is located in the southern half of Uintah County. This deposit is estimated to be 25 feet or more thick, and contain at least 25 gallons of crude oil per ton of oil bearing rock. The entire area covers about 1,200 square miles and is estimated to contain 90-115 billion barrels of crude oil.[2] For location of areas of potential oil shale development, see Figure 2.

The Bureau of Land Management (BLM) has set aside certain lands which are underlain by rich oil shale. The BLM has proposed a "Prototype Oil Shale Leasing Program" which involves two sites each in Utah, Wyoming and Colorado. Recently, the Utah and Colorado tracts were leased for developmental purposes by oil companies following BLM criteria.

The two Utah sites are adjacent to each other on the south side of the White River. Together the two tracts cover an area of 10,240 acres. Present plans call for the two tracts to be developed together and will, it is projected, support 100,000 barrels per day retorting plant. The removal process will be underground mining. Plans call for the mine to produce 160,000 tons of shale rock daily in order to produce 100,000 barrels of oil. The spent oil shale rock will probably be disposed of by land fill.[3]

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[2]Mark H. Horne, "Uintah Basin Study", Department of Natural Resources, January 1973.

[3]"Preliminary Development Plans for Federal Oil Shale Lands in Utah", submitted by Phillips Petroleum Co. and Sun Oil Co. of Delaware to the State Director, Utah's State Office of Bureau of Land Management.

An environmental baseline study of the oil shale tracts will commence the summer of 1974 and will continue two years. No construction will be permitted on the oil shale tracts until the baseline study is completed. After this study is completed and the results published, a final development plan will be published. This publication is to outline in detail the location of mines, equipment and water use.

Construction is presently scheduled to begin in the later part of 1977 and continue for about three years. Construction workers could number as high as 1,500. As construction is completed, about 800 production personnel are planned to be employed by 1980. Ultimately the number of production workers could reach 1,800.[4]

The specific production and employment plans of the oil shale companies are dependent on a variety of economic conditions. The development of oil shale as a mineral resource has long been anticipated by the residents of the Uinta Basin. This industry could easily develop into the largest industry in a here-to-fore agrarian economy. However, the development of this industry is still beclouded with many uncertainties, therefore projections concerning its economic impact will need to be reviewed as the anticipated schedule for development approaches.

Crude oil. Some projections have indicated that crude oil production in the Uinta Basin would top out about 1980, but recent discoveries have insured an expanding industry beyond this date. If the new fields are developed to the fullest extent, the ultimate recovery could amount to as much as one billion barrels, making the Uinta Basin one of the ten

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[4] Written communication from Michael B. Georgeson of the Central Utah Water Conservancy District on April 29, 1974, taken from Mr. Georgeson's notes of a program presented by representatives of Sun Oil Co. and Phillips Petroleum Co. at the annual meeting of the Vernal Chamber of Commerce held in Vernal, Utah on April 26, 1974.

largest on-shore discoveries in the United States. However, development of crude oil in this area is somewhat difficult due to the location, the physical nature of the hydrocarbon, the amount of gas which can legally be flared off, and high drilling costs.[5] However, these obstacles can be overcome, especially in the face of the current crude oil shortage.

Natural gas. Recoverable natural gas supplies in the Uinta Basin have been estimated to be between 1,000,000 and 2,000,000 MCF. Two natural gas refineries are in production at the present time with others being planned. Several gas fields have been developed in natural gas reservoirs below oil bearing rock in the rich oil shale areas.

Coal. Deposits of bituminous coal are found in the Uinta Basin, but exploration has been on a small scale and coal is mined for local use only. The outcrops of coal occur in three main fields. The Henry Fork Field in Daggett County contains several exposed coal beds ranging in thickness from less than one foot to ten feet. The thickest deposit is the Fraughton bed which is exposed in four locations and has a thickness range of 15 to 28 feet, the remaining beds attain a maximum thickness of about 18 feet. The Tabby Mountain field in Duchesne and Wasatch Counties contains 25 coal beds with a range in thickness from 6 inches to 28 feet.[6]

Gypsum. There are at least four known gypsum deposits in the Uinta Basin. Exploration and development of gypsum has not been extensive and therefore, knowledge about the quality and quantity of reserves is limited. The known reserves in the Basin are of low quality and have not been developed.

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[5]Mark H. Horne, "Uintah Basin Study", Department of Natural Resources, Division of Water Resources, January 1973, p. 90.

[6]Horne, p. 72.

Bituminous sands. Various kinds of bituminous sands, sandstone, asphalts and rock are found in the Basin. These sands and asphalts contain up to 15 percent hydrocarbon by weight and have only been used thus far for asphalt road paving. Approximately 90 percent of the reserve is contained in five major deposits. These deposits generally lend themselves to strip mining and could be a possible crude oil source. These sands have received attention from various sources at different times, but remain essentially undeveloped.

Nacholite and trona. These minerals occur in thin, small deposits scattered throughout the Basin. They are not attractive for commercial development alone but will be produced to a limited extent as a by-product of oil shale processing.

Water Resources.

Surface water. Surface water in the study area is confined mainly to the Duchesne, White and Green Rivers and tributaries. The Duchesne River originates high in the Uinta Mountains near Mount Agassiz in the northwestern corner of Duchesne County and runs southeast to Duchesne City. From the city of Duchesne the river flows in an easterly direction until it enters the Green River near the Indian town of Ouray in Uintah County.

The major tributaries of the Duchesne River are Rock Creek, Strawberry, Lake Fork and Uinta Rivers. These rivers drain part of the south slope of the Uinta Mountains. As the water reaches the lower plateau of the Uinta Basin most of it is diverted for irrigation which has the tendency of lowering the quality of the return flow. Most of the surface produced water is of relatively good quality until it reaches the basin floor. The upper reaches of the Duchesne River are characterized by a low concentration of calcium-bicarbonate ions. The concentration increases downstream and although sodium increases, it never presents a hazard to the use of the water.

The Duchesne River drainage system above the town of Duchesne has an area of 1,700 square miles consisting of 1,040 square miles on the Strawberry River and 660 square miles on the Duchesne River. The watershed ranges in elevation from 5,500 feet to 12,000 feet above mean sea level and is characterized by glaciated mountain slopes, steep canyons, relatively impervious bedrock and a comparatively shallow soil mantle which provides very little ground water storage. Consequently the runoff is rapid, contributing to wide seasonal fluctuations in stream flow. Runoff reaches its high state of 1,000 to 3,000 second feet at Duchesne City in May and June and falls off rapidly to a flow of 50 to 200 second feet in late summer.

The White River originates in Colorado and has a total drainage area of about 4,000 square miles. It enters Uintah County near Bonanza and continues westerly until it empties into the Green River near Ouray. The discharge of the White River is comparable to the Duchesne River although it has more than twice the drainage area. It winds its way through the driest part of the Uinta Basin. This dry area is the site of many of the oil shale leases and the federally leased oil shale tracts are practically adjacent to the White River on the south. The White River will probably be the source of most of the water needed for oil shale development in Utah and provide for part of the Colorado development.

The Green River is the major river of the Uinta Basin and originates in Wyoming. It is a cross axial stream as it crosses the eastern tip of the Uinta Mountains and flows eastward from Flaming Gorge Reservoir into Colorado before returning to Utah near Dinosaur National Monument. The

Green is by far the largest river in the Uinta Basin and has a drainage area of approximately 40,000 square miles. The major tributaries to the Green River in the study area are the Duchesne and White Rivers, itself being a tributary of the Colorado River south of Green River, Utah.

The surface water segment of the water supply has received the most attention in the Uinta Basin. The definition of water supply available for development has been of unique importance in this area since it is the most accessable portion of Utah's allotment from the Colorado River. Besides the physical and hydrologic constraints to development, there are the limitations of the Colorado River Compact and the Upper Colorado Basin Compact. These agreements restrict Utah's use of Colorado River water (which includes all tributaries) to about 1,438,000 acre feet per year. Table 1 shows present and committed uses of the allotment. Only 284,000 acre feet will be legally available for further development in the Colorado River system (which also includes San Juan, Grand, Carbon, Emery, Wayne and parts of Garfield and Kane Counties).[7]

Although Utah has been allotted 1,438,000 acre feet per year, it has been estimated by the Utah Division of Water Resources that in 1970 there was only 1,391,000 acre feet per year of water available for development.[8] Even though there is 284,000 acre feet per year legally developable, only 237,000 acre feet per year is available to be developed in the average year.

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[7]Bruce Thurston (U.S. Bureau of Reclamation), Carl Carpenter (Central Utah Water Conservancy District), Don Price (U.S. Geological Survey) and Barry Saunders (Department of Natural Resources, Division of Water Resources), "Water Resources, Uintah Resource Study," July 1973, p. 7.

[8]The Utah Division of Water Resources estimates that 40,000 acre feet per year of the 1,359,000 acre feet per year to be ground water. This means 1,319,000 acre feet per year of surface water is available for development.

Table 1. Present and committed Colorado River use (acre feet)

	Uinta Hydrologic Unit	West & S.E. Colorado Hydrologic Units	Total
Committed Uses			
New Land Irrigation	51,000	---	51,000
Supplemental Irriga.	57,000	---	57,000
Municipal & Indus.	13,000	---	13,000
Thermal Power	---	102,000	102,000
Bonneville Export	155,000	---	155,000
Subtotal	276,000	102,000	378,000
Present Use			
(including exports)	469,000	195,000	664,000
Subtotal	745,000	297,000	1,042,000
Mainstem Evaporation	---	---	152,000
Subtotal			1,194,000
Less Salvage			-40,000
Net Present & Committed Consumptive Use			1,154,000

Source: Mark H. Horne, "Uinta Basin Study", Department of Natural Resources, Division of Water Resources, January, 1973, p. 100.

Committed uses include the transfer water for the Bonneville Unit of the Central Utah Project (CUP), and water for 29,000 acres of new irrigated land committed to the Ute Indian Tribe in connection with the Bonneville, Uintah and Upalco Units under deferral agreements with the Federal Government.[9] HSU 7 may be charged to supply one half the water allocated to the Upper Colorado River Basin to fulfill the currently debated Mexican Treaty. This amounts to 161,000 acre feet per year and would mean that only an additional 43,000 acre feet per year are available for further development within the state.

Salinity is a major water quality problem in the study area. Nearly all the surface water within the area, including irrigation canals, has a total dissolved solid concentration of less than 1,000 parts per million. Water of this quality is considered suitable for continued use as irrigation water, and would be suitable for culinary uses (less than 500 ppm) with proper treatment. During parts of some years, however, the canal water may approach a salinity concentration of 1250 parts per million. This water could still be treated for culinary purposes but should be used for only short durations for irrigation to prevent adverse effects. The flow of the Green River as it enters Utah averages 380ppm. High quality inflows of the Little Snake and Yampa Rivers reduce this to 320 ppm at Jensen. The concentration of total dissolved solids increase to 450ppm at Green River, Utah due to poorer quality inflows from the White River, Duchesne River and agricultural return flows.

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[9]Mark H. Horne, "Uinta Basin Study," Department of Natural Resources, Division of Water Resources, January 1973, p. 1.

Currently, the present and committed consumptive use of the allotted amount is 745,000 acre feet per year within the Uintah Hydrologic Unit. Present and committed uses in other hydrologic units of the Colorado River total 297,000 acre feet per year. This totals to 1,042,000 acre feet per year of consumptive use of Colorado Compact allotments. Adjusting these figures for evaporation and salvage leaves 1,154,000 acre feet per year for present and committed uses. The 1,438,000 acre feet per year is the maximum amount of water legally available for development as stated by the Upper Colorado River Basin Compact. This does not mean that the entire amount is available for development. It has been estimated that only 1,391,000 acre feet per year of water can be developed. In other words, Utah was allotted the right to develop more water than is produced by the watersheds of the Basin. (See Table 2.)

Table 2. Developable water in Utah with and without Mexican Treaty charge (acre feet)

	Without Mexican Treaty Charge	With Mexican Treaty Charge of 161,000 acre feet per year
Total water legally developable	1,438,000	1,277,000
Total water estimated to be available	1,391,000	1,230,000
Present and committed uses	1,154,000	1,154,000
Uncommitted supply	237,000	76,000

The rivers and streams of the study area flow most of the year, with spring high flows reducing to low flows in the summer being due to the rapid runoff from snowmelt in the spring; and large diversions for irrigation purposes during the irrigation season. Flows of the main study area streams are displayed in Table 3.

Lakes and reservoirs. There are numerous lakes and reservoirs within or near the study area. Some are too small and distant to be considered as likely sources of supply to meet future municipal and industrial water demands but contribute to the water resources of the county and are therefore worthy of mention.

Starvation Reservoir was formed by a dam on the Strawberry River 4 miles upstream from Duchesne City and 33 miles downstream from Strawberry Reservoir. Construction began on March 20, 1967 and the project was completed March 31, 1970. The reservoir receives most of its water from the Duchesne River which is diverted at the Knight Diversion. It also stores water from the Strawberry River below Strawberry Reservoir. Two dikes, in addition to the dam, were required to contain the reservoir. The reservoir has a total capacity of 162,000 acre feet, including 147,800 acre feet of active capacity, 1,000 acre feet of inactive capacity and 14,000 acre feet of dead storage. It also has a surcharge capacity of 36,000 acre feet.

Sediment is expected to occupy 17,300 acre feet of storage space in 100 years, of which 7,800 acre feet will be deposited in the active pool and 9,500 acre feet in the inactive pool. The reservoir has a surface area of 2,760 acres at normal water surface elevation of 5,749 feet. With proper treatment, Starvation Reservoir is an excellent source of supply to meet future municipal and industrial water demands within Duchesne County.

Table 3. 12 year flows of major study area streams (acre feet per year)

	Lake Fork near Mt. Home	Rock Creek near Mt. Home	Duchesne River near Myton	Strawberry River at Duchesne	Yellowstone River near Altonah
1960	66,280	93,610	114,000	37,300	70,870
1961	43,850	78,020	90,640	29,920	70,250
1962	119,400	150,000	355,300	122,100	120,500
1963	82,400	111,300	155,000	63,080	94,210
1964	105,700	134,700	254,215	77,420	59,594
1965	120,500	186,400	588,600	143,900	162,800
1966	102,900	98,180	206,900	82,780	99,080
1967	111,500	153,500	419,800	129,000	127,000
1968	113,600	146,600	380,600	149,600	129,500
1969	116,900	138,800	443,000	150,400	122,900
1970	83,330	109,500	97,050	84,960	88,120
1971	98,820	145,400	249,400	86,620	108,900
AVERAGES					
Number of years over which average was taken:					
	30	35	64	53	28
Yearly Average:					
	93,460	125,300	386,200	109,300	101,400

Source: U.S. Department of the Interior, Geological Survey, "Water Resources for Utah, Part 1 - Surface Water", 1960-1971

Table 3. Continued

	Uinta River near Neola	Green River near Ouray	Green River near Green River, Utah	White River near Watson
1961	107,400	2,088,000	2,026,000	345,700
1962	163,300	5,789,000	5,829,000	667,600
1963	120,000	1,624,000	1,663,000	337,000
1964	149,600	2,817,000	2,784,000	396,100
1965	236,000	5,060,000	5,134,000	565,800
1966	126,400	3,195,000*	3,211,000	364,800
1967	173,500		3,999,000	386,200
1968	177,700		4,651,000	473,000
1969	166,500		4,920,000	481,700
1970	130,300		4,268,000	564,500
1971	139,700		4,057,000	531,000
AVERAGES				
Number of years over which average was taken:				
	44	18	72	48
Yearly Average:				
	130,400	3,930,000	4,607,000	509,300

Source: U.S. Department of the Interior, Geological Survey, "Water Resources for Utah, Part 1 - Surface Water", 1960-1971

The proposed Taskeech Reservoir is planned primarily to provide supplemental irrigation water for Indian and non-Indian lands along the Lake Fork River in the existing Moon Lake and Uinta Indian Irrigation Projects. Taskeech Reservoir will regulate Lake Fork River flows not stored in Moon Lake Reservoir. In addition, it will store surplus Yellowstone River flows that will be diverted at the Boneta Diversion Dam and conveyed to the Lake Fork through the Taskeech feeder canal.

Water from the reservoir will be released to the Lake Fork River. Part of the reservoir water will be distributed in the Lake Fork drainage by a number of existing canals which divert water from the river, including the Farnsworth, Boneta, South Boneta, Purdy, Uteland, Red Cap, Hamilton, U.S. Lake Fork, Dry Gulch No. 1, Class C and Lake Fork Irrigation Company. Taskeech Reservoir will be formed by a dam and a small dike. The dam will be on the Lake Fork River about 6 miles downstream from the existing Moon Lake Dam and 11 miles northwest of Altonah. The reservoir will have a capacity of 78,400 acre feet, including an active capacity of 66,000 acre feet for joint use and a dead and inactive pool of 12,400 acre feet for fish and wildlife. A surcharge capacity of 7,200 acre feet will be provided. At normal water surface elevation, 7,628.3 feet, the reservoir will cover an area of 1,223 acres.

The proposed Uinta Reservoir on the Uinta River will be located on the Uintah and Ouray Indian Reservations about 8 miles northwest of Neola, Utah and about 1 mile upstream from the existing Uintah hydroelectric power plant. The reservoir will have a total capacity of 47,030 acre feet and a surface area of 736 acres at normal water surface elevation 7236.5 feet above sea level. About 35,030 acre feet of the capacity will be active and 12,000 acre feet inactive and dead storage. A surcharge capacity of 10,220 acre feet will be available.

This proposed reservoir would provide water for irrigation of Indian and non-Indian land, and municipal and industrial water supply for the city of Roosevelt and vicinity. The Uinta and Taskeech Reservoirs, like Starvation Reservoir, would be administered by the Central Utah Water Conservancy District in cooperation with the Bureau of Reclamation. The quality of project water for culinary use would depend on the diversion point of the water. Water obtained from the project reservoir would be of excellent chemical quality for irrigation but would require treatment for municipal and industrial use.

Big Sand Wash Reservoir, with an active capacity of 10,800 acre feet, is located on Big Sand Wash. It was constructed in 1964 by the Moon Lake Water Users Association to supplement water supplies for the Moon Lake Project area. The reservoir stores Lake Fork River flows diverted through the Class C canal and a short feeder canal with some additional water from Big Sand Wash. The major portion of the storage water is conveyed directly from the reservoir through a short service canal back to the Class C canal for distribution. A small portion of the water is released to Big Sand Wash for diversion by the Hancock lateral.

Twin Potts Reservoir, with an active capacity of about 3,700 acre feet, is located at an offstream site on the Uintah and Ouray Indian Reservation about a half mile west of the Lake Fork River and about 6 miles downstream from Moon Lake Dam. Water from Lake Fork is delivered to the reservoir through the Farnsworth Canal, while water from the reservoir is released through a natural drainage way back to the river. The reservoir was constructed by the Farnsworth Canal and Reservoir Company for the storage of Lake Fork River water when Moon Lake Reservoir is full or is forecast to spill. It provides a small amount of supplemental irrigation storage and is a popular fishery.

The Moon Lake Reservoir was constructed by the Bureau of Reclamation and has been operated by the Moon Lake Water Users Association since 1938. The project provides irrigation water for about 75,000 acres of non-Indian land along the Lake Fork, Yellowstone and Uinta Rivers. Moon Lake Reservoir, with an active capacity of 35,800 acre feet, is on the upper Lake Fork River and regulates the flow of that river. Water is diverted to lands in the Uinta River drainage from Yellowstone River through the Yellowstone Feeder Canal. Lands along Lake Fork River receive stored water released to the river while lands along the Uinta and Yellowstone Rivers receive direct flows in exchange for storage water. Irrigation waters are conveyed from the rivers through a series of canals constructed and operated by various members of the Moon Lake Water Users Association.

Fourteen lakes in the Uinta Mountains have been developed by local interests for storage of irrigation supplies in the project area. These have an active capacity of approximately 7,420 acre feet. They include the Clements, Kidney, Island and Brown Duck Lakes on Lake Fork River; Milk, Superior, Five Point, Drift and Bluebell Lakes on Yellowstone River; and Timothy, Farmers, White Miller, Deer and White Lily Lakes on Swift Creek.

Starvation and Big Sand Wash Reservoirs are currently the only reservoir sources, within close proximity of the populace that could be used to meet future culinary water demand provided the water is properly treated. The proposed Uinta, Taskeech and Harmston Reservoirs are also likely sources, but are still awaiting federal approval and funding before construction can begin.[10]

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[10] Horrocks & Associates Consulting Engineers, Duchesne County Municipal & Industrial Water Study, July 11, 1974, Chapter 3.

Construction of the Vernal Unit, which is part of the initial phase of the Central Utah Project, was initiated during 1959 and completed in 1962. This was the first year agricultural lands received supplemental irrigation water from the project. The principal feature of the project is Steinaker Reservoir, which is located in Steinaker Draw 4 miles north of Vernal. The earthfill dam is 140 feet high and forms a reservoir having a total capacity of 37,200 acre feet, of which 33,100 acre feet is usable storage capacity. Water is diverted from Ashley Creek at the Fort Thornburgh Diversion Dam into the Steinaker Feeder Canal, which has a capacity of 400 second feet. The Steinaker Feeder Canal conveys the water from Ashley Creek to Steinaker Reservoir. A canal from the dam to Ashley Valley serves to bring agricultural water to the north end of the valley. Vernal and Maeser cities also draw on this supply for municipal use.

Flaming Gorge Dam is located on the Green River in northeastern Utah about 32 miles downstream of the Utah-Wyoming boarder. The reservoir extends up the Green River Gorge to Green River, Wyoming. The dam was completed and started storing water on November 1, 1962. The active capacity of the reservoir is 3,516,000 acre feet and dead storage is an additional 273,000 acre feet.

Flaming Gorge Dam and Reservoir has multi-purpose objectives. As part of the Colorado River Storage Project, this reservoir is a portion of the long range basin-wide program to develop the water resources of the Upper Colorado River System, regulate the flows of the Green River and produce hydroelectric power for financing the basin-wide water resources program of the Upper Colorado River System.[11]

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[11] Lloyd H. Austin, Water Management Alternatives in the Uinta Basin, unpublished Master's Thesis, Utah State University, 1970, p. 36-38.

Ground water. Much of the ground water in the study area comes from shallow aquifers (less than 100 feet deep) which have a very high permeability and are able to transmit water quite rapidly. These aquifers exist chiefly along or near active streams and consist of glacial outwashes of unconsolidated, generally unsorted to poorly sorted silt, sand, gravel and boulders which average approximately 50 feet in depth.

Below the glacial deposits is the Duchesne River Formation which consists of consolidated sandstone with much less permeability than the glacial deposits. Yields from this formation are generally less than from glacial outwashes. This formation is less subject to contamination from surface wastes that infiltrate into the soil because it is thicker and deeper than the shallow alluvial deposits. Beneath the Duchesne River Formation is the Uinta Formation. It, too, has a low permeability and yields are low similar to the Ducesne River Formation.

In most cases the chemical quality of the ground water is acceptable for culinary use. Spring water from quartzite or limestone has the best chemical quality. Water from the Ducesne River Formation is generally of better quality than water from the shallow alluvial deposits. Many of the shallow wells in the glacial outwash have a poor water quality composition and are not supplying sufficient water to meet the current demand. Deep wells into the Uinta Formation yield water which is slightly saline.

Springs. Springs within or near the study area currently supply approximately 45 per cent of the necessary water to meet the present municipal and industrial water demand of the study area. The larger developed springs along with some of the major springs that are developed, or used for other than culinary uses, are listed in Table 4.

Table 4. Major springs in the study area

SPRING NAME	AQUIFER TYPE	DISCHARGE VOLUME (cfs)	TDS (ppm)
Uriah Heap Springs	glacial outwash	8	265
Neola Springs	glacial outwash	0.8	374
Indian Big Spring	limestone	6.5	80
State Fish Hatchery	glacial outwash	8	263
Ute Tribe Spring	glacial outwash	1	595
Miners Gulch	limestone	20	63

Roosevelt City has rights to 4 second feet of water from the Ute Indian-owned Uriah Heap Springs. The Ute Indian Tribe is currently planning to develop the Big Springs on the Uinta River which will supply an additional 5 second feet to the Roosevelt City culinary water system. The only other spring in the study area used for culinary uses is one at the town of Neola that discharges about 350 gpm.

Several springs north of Altonah could yield 4 to 5 second feet if fully developed and four to five springs located on both sides of Rock Creek near Miners Gulch Campground have a firm yield potential of more than 20 cubic feet per second.

Wells. Wells within the study area currently supply a portion of the water for culinary usage. Roosevelt City has rights to 1,720 acre feet per year from the Campbell Wells northwest of town. Three of the five proposed Campbell Wells have been completed to depths averaging 850 feet into the Duchesne River Formation. The Ducesne River Formation dips southerly allowing a hydraulic head to build up from the north causing these wells to flow under pressure. Because of the low transmissibility of the formation, draw downs necessitate well spacing of approximately 4,000 feet.

The remainder of wells within the study area consist of shallow wells, usually less than 100 feet, into glacial deposits. Some of these shallow wells should be abandoned due to poor chemical quality. (See Table 5)

Table 5. Major wells in the study area

SOURCE	QUANTITY (gpm)	AQUIFER TYPE	QUALITY (TDS)
Campbell Wells	1066	Duchesne River Formation	258
Duchesne City	1000	glacial outwash	514
Altamont	200	glacial outwash	374
Johnson Water	500	glacial outwash	796-1090
Arcadia Area	45	glacial outwash	NA*
Private Wells	5	glacial outwash	NA*

*Not Available

History

The first explorers of the Basin area were two Franciscan friars, Fathers Escalante and Domingues. These explorers first came into the area in 1776 in search of a shorter overland route to Monterey, California. Even though they never found the shorter route, they explored and prepared rough maps of the area.

About fifty years later General William Henry Ashley of the Rocky

Mountain Fur Company brought a group of trappers to the Basin and established a trading post. Although several trading posts were set up in the area, they were all eventually destroyed by Indians. As late as 1878 there were only about 100 white persons in the Uintah Basin.[12]

In the early 1860's President Lincoln signed the acts setting aside two large land areas in the Uinta Basin as Indian Reservations. The Uinta Utes of Utah and the Uncompahgre Utes and White River Utes of Colorado were each given land. In 1868 Pardon Dodds established the Whiterocks Indian Agency and became one of the earliest permanent white settlers in the Uinta Basin. Mr. Dodd's settlement opened the way for the discovery of Gilsonite in 1869.

With the discovery of Gilsonite came the construction of a narrow gauge railroad in 1903. This railroad took Gilsonite ore from the mines around Bonanza, Utah to the refinery in Grand Junction, Colorado. The Uintah Railway Company served the passenger and freight needs of this part of the Basin until 1937. In 1937 the railway was abandoned and torn up due to the innovation of truck transportation.[13]

Historical Population. Virtually all the inhabitants of the Uinta Basin live in Uintah, Duchesne and Daggett Counties. The only racial classifications in these counties are Native Indian and White. The majority of Indians live on reservation lands in Uintah County. (See Table 6.)

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[12] Henry H. Bender Jr., Uintah Railway, Gilsonite Route (New York: Howell-North Books, 1971), page 10.

[13] American Gilsonite Company, "Gilsonite Guidebook" Salt Lake City, Utah, 1969, p. 11-12.

The relatively large 1960 Daggett County population and subsequent decline is related to the construction and completion of Flaming Gorge Dam. The decline of population from 1940 to 1960 in Duchesne County is largely attributed to the declining need for labor in agriculture. In the same period Uintah County population remained stable because of expanding oil and tourist industries.

Even though the population of Uintah County is shown to be increasing, the increase was less than the normal increase due to the birth rate. This reflects a net out-migration of people. Out-migration has been a common population characteristic of the Uintah Basin Counties. The increasing population of Duchesne and Uintah Counties in recent years is the result of construction on the Central Utah Project and current oil industry explansion.

Economy. Historically the Uintah Basin economy has been centered around agriculture, particularly the livestock industry. Grazing is the major land use. Cattle, sheep, wool, milk and hay are the major agricultural products of the region. Most feed crops are grown in the area including corn, hay, alfalfa, oats, wheat and barley. The Uinta Basin is one of the state's major honey producing areas.

In 1962 agricultural employment constituted 21.6 percent of all employment in the Uinta Basin Counties. By 1973 the percent of agricultural employment decreased by half. The actual number of people employed in agriculture fell from 1,800 to about 800 in ten years. This decrease in the agricultural demand for labor has caused a historical net out-migration of people from the Uinta Basin.

The migration situation was reversed shortly after 1970 when crude oil exploration began in full scale. Since that time the population of

Table 6. Population (to nearest hundred)

	Daggett	Duchesne	Uintah	Total
1920	400	9,100	8,500	18,000
1930	400	8,300	9,000	17,700
1940	600	9,000	9,900	19,400
1950	400	8,100	10,300	18,800
1960	1,200	7,200	11,600	19,900
1970	700	7,400	12,800	20,800
1971	700	7,900	13,300	21,900
1972	700	9,700	14,400	24,800
1973*	700	13,800	14,900	29,400
Indian population				
	Daggett	Duchesne	Uintah	Total
1920	0	80	1,133	1,213
1930	0	203	783	986
1940	7	179	1,031	1,217
1950	0	222	1,076	1,298
1960	3	332	1,190	1,525
1970	0	321	1,337	1,670

*1973 Estimates based on water meter connections and number of residences in rural communities

Source: Mark H. Horne, "Uinta Basin Study", Department of Natural Resources, Division of Water Resources, January 1973, p. 35.

the study area has almost doubled. This rapid population increase has brought with it increasing strain on the water and sewer facilities in the towns of the Uinta Basin. Growth has been somewhat haphazard, resulting in various urban problems.

After agriculture, the next major employers are government and mining. As a result of recent construction on the Bonneville Unit of the Central Utah Project, government employment has been increasing. Government employment varies considerably with the level of construction activity. Mining is mainly centered around oil exploration and development. This industry has shown a steady increase in recent years and is expected to increase more rapidly in the near future.

Construction and production of natural gas plants in the area have recently caused some increase in employment and it is expected that the natural gas industry will continue to grow with crude oil development. Exploration and drilling for crude oil has also been of major importance to the economy of the area.

Although the major industries have caused a significant population influx, the influx of service population has been somewhat lower than would ordinarily be expected. The reason for this has been the simplicity of the Uinta Basin economy. If an economy has one major industry, the requirement for service personnel for this industry will be lower than if different industries are present in a more complex economy.

It is expected that as the crude oil industry of the Uinta Basin expands, more horizontal and some vertically related industries will enter the economy. Horizontal industries such as natural gas and vertical industries such as gasoline refineries will add complexity to the economy and thus increase the number of service personnel associated with the injection of each new job into the economic base. As this number increases, the rate of population growth will increase, if other economic conditions remain the same.

The tourist industry has been a major contributor to the Uinta Basin economy for some time. Much of this activity is related to water development such as Flaming Gorge, Starvation and Strawberry Reservoirs. The status of the tourist industry has recently become somewhat uncertain because of recent price increases in gasoline and motor oil; however, it is expected to continue to make a major economic contribution to the economy of the Uinta Basin area.

Transportation. The Uinta Basin contains 836 miles of surfaced roads and 2,426 miles of graveled or unsurfaced roads for a total of 3,300 miles of roads in Daggett, Duchesne and Uintah Counties. U.S. Highway 40 is the major transportation route in the region. It crosses the Basin connecting Duchesne, Roosevelt and Vernal with Salt Lake City on the east and with Colorado on the west. Daggett County is linked to U.S. Highway 40 by Utah State Highway 44 from Vernal. There are no railroads in the Uinta Basin at the present time. Vernal maintains a commercial airport, and several other communities in the Basin maintain airstrips for small aircraft. Roosevelt City presently has an airfield and has recently released plans for the construction of a municipal airport. At the present time several oil and gas pipelines lead out of the Basin.

DETERMINATION OF THE PRESENT SUPPLY AND DEMAND SITUATION

Any commodity or service sought to satisfy someone's desires is subject to the economic laws of the market place, if the quantity of that good or service is sufficiently limited. Water, as an economic good, is subject to these laws just as any other commodity. All economic goods are subject to the laws of diminishing marginal utility and diminishing marginal productivity, but the particular character and situation of each good, in this case water, determines the specific position of that good in the market structure.

As the productivity of each additional or marginal unit decreases, its value also decreases because the quantity added to the total becomes less and less as each unit of water is used. This means the value of each additional unit of water will also be less if there are no changes in demand or the production processes. This marginal value productivity is a phenomenon which individual water users in an economy will face, and is represented by Figure 3.

The curved line in Figure 3 represents the value or worth of each additional quantity of water as measured along the horizontal axis. It is noted that if there is a sufficient increase in the quantity of water used, say from OQ to Q_2, then there will be a decrease in the value of the marginal unit from OP to OP_2. The values of OP, and OP_2 are representative of the price paid for all the water up to Quantity OQ_2.

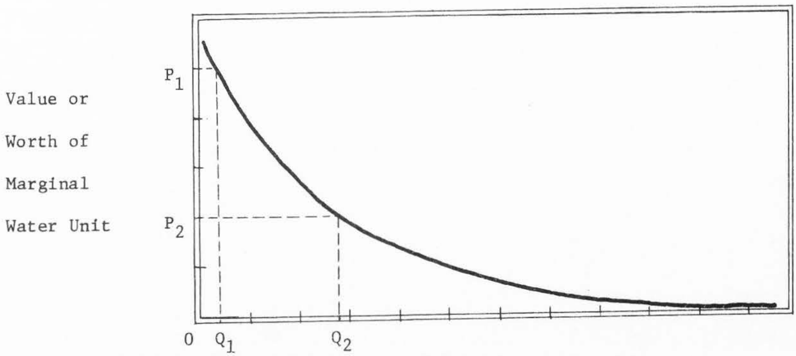

Figure 3. The marginal value of additional units of water (hypothetical)

The reason the demand curve slopes downward to the right is because there are certain uses for which an individual will pay handsomely, but as that want is satisfied he will pay less for the next unit he will use to satisfy some lesser want. Some higher uses of water are for drinking and cooking while some lower wants may be for yard use, such as lawn irrigation.

Some users place different orders on the rank of water uses from higher to lower. An example might be where industrial or agricultural users may not be willing to pay as much for water as would a thirsty person who needed it to sustain life. This idea is illustrated in Figure 4.

Curve A in Figure 4 represents household consumers. As can be seen, they are willing to pay the highest price for water up to quantity 0 Q_1. At this point non-agricultural, commercial and industrial users are

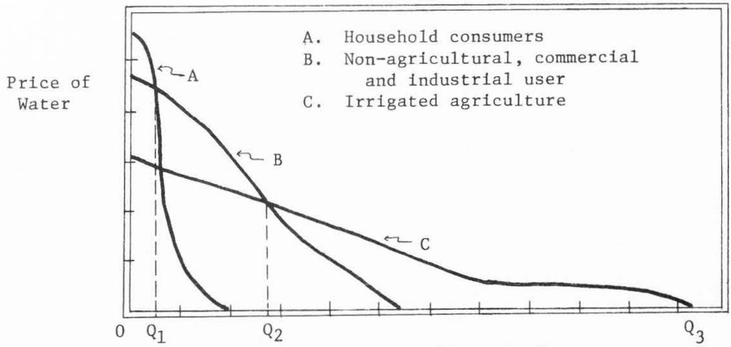

Figure 4: Aggregate Marginal Demand Curves for Water for Several Types of Users (hypothetical)

willing to pay the highest price until quantity OQ_2 is reached. Irrigated agriculture commands the highest marginal productivity of the marginal water unit to Q_3. The price paid for agricultural water is low and the marginal demand curve does decrease slowly to the right but it is noteworthy that the amount $0\ Q_2$ to $0\ Q_3$ is larger than the amounts used by households and industry together. Although this is a hypothetical case, the tendacy for agriculture to be a large user of low priced water has been the subject of other studies.[1]

If the price of water in a given area increases, there will be changes in the quantities of water used by the different consumer groups. Figure 5 depicts an increase in the price of water from OP_1 to OP_2.

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[1] Maurice M. Kebo, William E. Martin and Lawrence E. Mack, Water Supplies and Economic Growth in an Arid Environment: an Arizona Case Study, University of Arizona Press, Tucson, Arizona, 1973, p. 28-40.

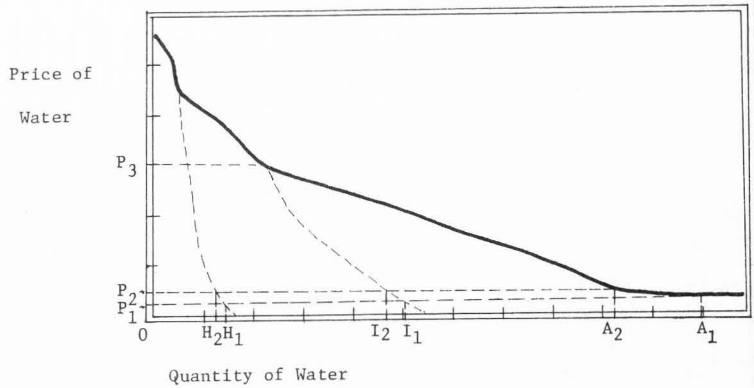

Figure 5. Composite aggregate marginal demand curive for water with a change in water cost

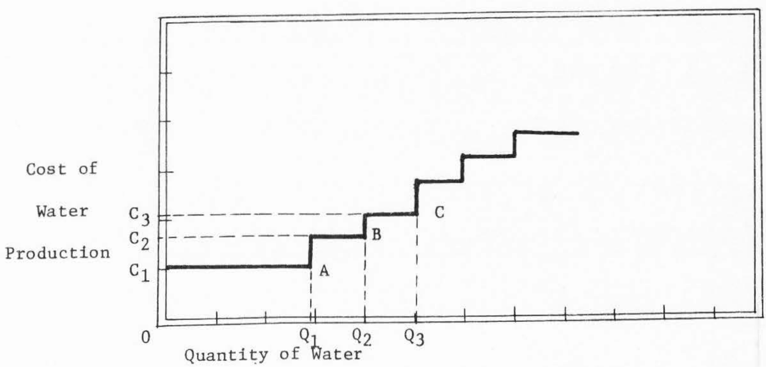

Figure 6. Marginal supply curve of water (hypothetical)

This price increase lowered the quantity of household water used from OH_1 to OH_2, the quantity of industrial water from $H_1 I_1$ to $H_2 I_2$, and the quantity of agricultural water was reduced from $I_1 A_1$ to $I_2 A_2$, substantially more than the other two sectors as a result of the same price increase.

Agricultural water use accounts for most of the reduction in water use for a specified price increase. The irrigated agriculture industry is not only the largest water user in the study area but is also the marginal industry in terms of productivity. This is why the greater effect is felt in the agricultural sector of the economy when water prices are increased. If the price increased as high as P_3, it would mean that agriculture would not be able to compete effectively for any of the static water supply.

The static water supply in a region is determined by the cost of development of successively more expensive water sources. The character of water development is such that large indivisible blocks are developed, and as a result form a marginal supply curve such as that depicted in Figure 6. Examining Figure 6 reveals that if cost C_1 is necessary to produce quantity Q_1 of water in project A, the same price will need to be charged for all the water developed in project A to cover cost C_1. This price will hold until all the water in project A is committed or used. When all this water is used the next least costly source to develop the source for project B will come on line at a higher cost and consequently a higher price. Successive projects will be constructed until the supply of water is large enough to satiate the demand at a price mutually agreeable to suppliers and demanders.

If the supply curve is superimposed on the demand curve discussed earlier, the result would be similar to that illustrated in Figure 7. It can be seen that all of the water from projects A, B and C is being used and that the demand will have to increase enough to bring the price to P_2 before project D can be justified financially.

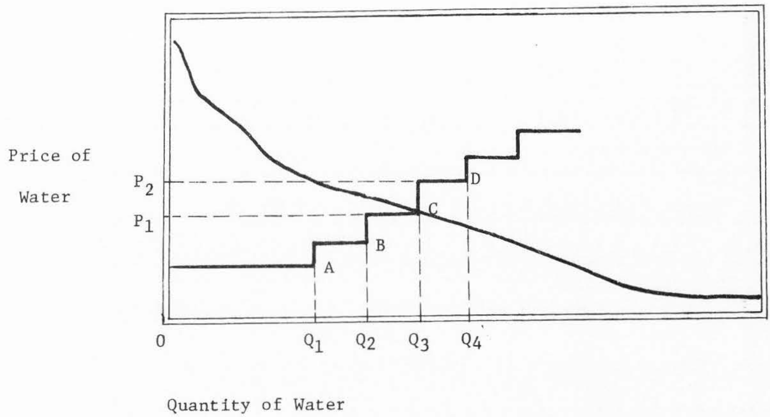

Figure 7. Aggregate marginal supply and demand curve for water in a given area

The results of this shift will be that demanders will want amount Q_4 of water at price P_1 but only Q_3 will be available. As a result of more water being wanted than is available, demanders will be willing to pay price P_2. However, some buyers cannot afford to pay price P_2 because of that particular individual's cost structure.

Resulting from this inability to pay P_2, the water they would have used at price P_1 will be bid away by those buyers who can afford to pay the higher price. This will be the situation in the Uintah Basin if demand increases enough to push the MVP curve beyond the intersection of the P_1 price line and the supply curve.

The schematic form of the water budget will be used to discuss the supply and demand situation and will depict the present water allocation situation in the Basin. (See Figure 8). Water budgets are a useful tool for analyzing and describing the water resource allocation of a particular area. In the water budget approach, inflows and outflows of water to a specific geographic area are measured or estimated for particular limits of time (the budget used will be based on yearly averages). Examples of inflows are river flow, precipitation and imports of water by canals or pipelines from other river basins.

Outflows include rivers flowing out of the Basin, exports, consumptive use by cropland, evaporation, domestic uses, and marshlands. Since inflows must equal outflows plus changes in storage, preparation of a water budget quickly reveals gaps in information and often improves the quality of estimates.[2]

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[2] Bruce Thurston (U.S. Bureau of Reclamation), Carl Carpenter (Central Utah Water Conservancy District), Don Price (U.S. Geological Survey), Barry Saunders (Department of Natural Resources), "Uintah Resource Study", July, 1973, p. 3.

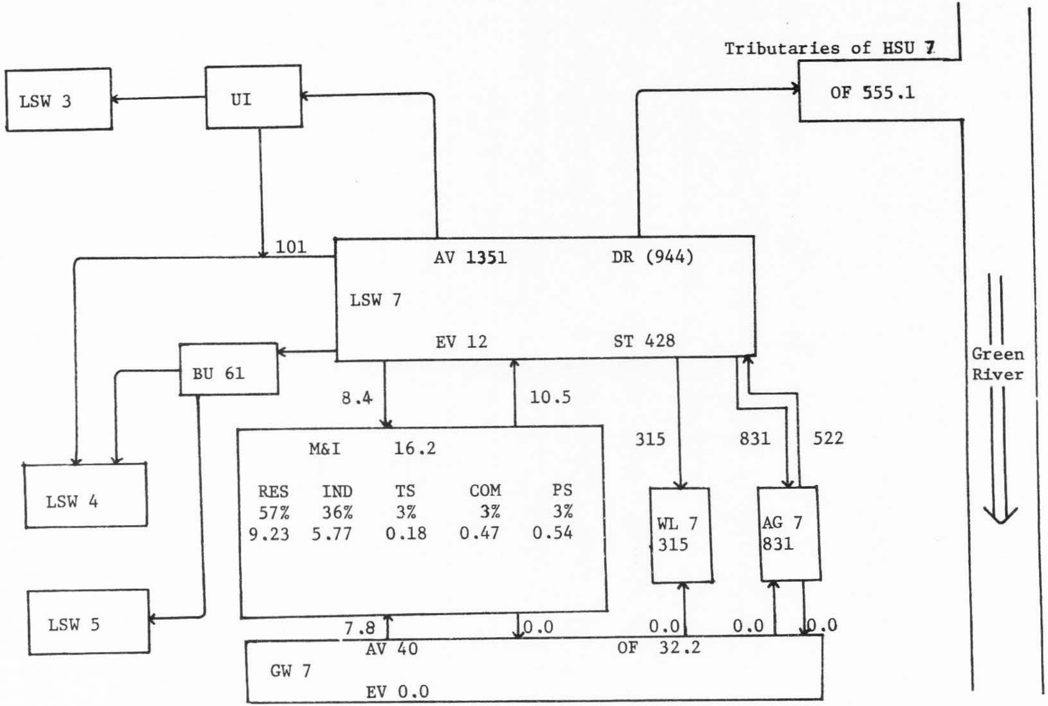

Figure 8. Uintah Basin water budget as of December 31, 1973
(all figures are in 1,000's of acre feet per year)

An example of a schematic water budget is shown in Figure 8. The definitions of the abreviated terms are as follows:

M & I - Municipal and Industrial water, includes water used in the five areas listed below;

RES - Residential water, includes all water used in residences as household domestic water. In some cases small amounts of stock water is included in RES, inasmuch as the water metered to a residence or drawn from a well could not be separated into stock water and household water on an accurate basis. The practice of drawing stock water from the same well or meter as house water will always be a characteristic of the residents of the Basin and the percentage to each use will be assumed to remain constant in the future.

IND - Industrial use of water, includes all water used by manufacturing and mining (Most of IND water is used in connection with the oil industry.)

TS - Travel services, includes all water used in restaurants, gasoline service stations, motels and all travel and tourist related water use

COM - Commercial, includes water used in all commercial businesses

PS - Public services, includes all water used in municipal, county, state, and federal government buildings as well as water used in public parks, cemeteries, churches and other civic organizations

BU - Inter-basin transfer of the Bonneville Unit of the Central Utah Project

UI - Inter-basin transfer of the Ute-Indian Unit of the Central Utah Project

WL - Wetlands requirement

AG - Diversion for agricultural use

LSW - Local surface water, includes springs, rivers and precipitation

GW - Ground Water, includes all reserves of water in ground water quifers but does not include spring water and artesian wells

AV - Water available for development

EV - Evaporation loss

DR - Draft requirement

ST - Storage requirement

OF - Outflows

A water budget that will best depict the present situation was used as a base for the budget in Figure 8. The budget assumes that the inflow into the Great Salt Lake will be greater than 800,000 acre feet per year but less than 1,014,000 acre feet per year. The present inflow into the Great Salt Lake is 1,014,000; therefore, the model assumes that the Great Salt Lake will decrease in size but will not go below the level maintainable by an inflow of 800,000 acre feet per year.

To arrive at the present (1973) budget in Figure 8, the 1965 to 1976 budgets of King's publication were used.[3] Since King used the linear programming approach, extrapolations between the two dates were made. Extrapolations will be made for EV, DR, ST, WL, and AG. All other figures can be documented by some other means.

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[3] Alton B. King, Jay C. Andersen, Calvin G. Clyde, Daniel H. Hoggan, Development of Regional Supply Functions and a Least-Cost Model for Allocating Water Resources in Utah: A Parametric Linear Programming Approach. Utah State University, Utah Water Research Laboratory, Logan, Utah, June, 1973, p. 113-114.

Each blank in the diagram deserves explanation. The figures not in parentheses are the figures unaltered from the 1965 budget. The figures in parentheses were arrived at by extrapolation or direct original research. The same budget is presented in tabular form in Table 7.

Starting in the upper left hand corner, each water-use figure will be discussed. The Ute Indian Unit (UI) of the Central Utah Project has not been constructed at this time. Construction of this Unit is now pending congressional approval. The Ute Indian Unit is the largest of all the Central Utah Project units and is presently designed to provide an inter-basin transfer of 390,000 acre feet per year. The project will cost $620 million (at 1972 prices) and annual operation and maintenance costs are estimated to be $470,000 (at 1972 prices).

In the interest of the Bonneville Unit development, the Ute Indians have agreed to defer irrigation of 14,242 acres of reservation lands to not later than the year 2005.[4] It is not known at the present time when construction will begin on the Ute Indian Unit but it must be some time before 2005 if agricultural water is to be delivered to the Indians by this date.

Immediately below the UI hexagon is an arrow with the figure 101 in it. This represents the present inter-basin transfer through the Strawberry tunnel.

The BU hexagon is the next figure below the Strawberry transfer. The Bonneville Unit is not completely built, but is presently diverting

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[4] U.S.Bureau of Reclamation, Department of the Interior, "Summary Sheets of the Units of the Central Utah Project," 1973, Ute Indian Unit, p. 1-3.

Table 7. Tabular presentation of schematic water budget (1,000's of acre feet per year)

Item	Net Use	Available Water
Evaporation	12	
Strawberry diversion	101	
Bonneville Unit diversion	61	
Municipal and Industrial	5.7	
Wetlands	315	
Agriculture	309	
Surface water outflow	555.1	
Ground water outflow	32.2	
Available ground water		40
Available surface water		1351
	1391	1391

61,000 acre feet per year out of the Basin.

The available local surface water (AV) of HSU7 has been estimated to be 1,351,000 acre feet per year. This figure is based on measurements made by the State Division of Water Resources.

The evaporation (EV) figure of 12,000 acre feet per year is based on a storage requirement of 428,000 acre feet per year. If the storage requirement increases, evaporation will increase.

The draft requirement (DR) will also vary with the storage requirement. The draft requirement is defined as the amount of water that must be diverted from streams or collected from other sources to ensure that the level of water to be maintained in storage reservoirs will meet all the required uses or outflows at a certain reasonable probability level.

As the demand for water increases the draft requirement will increase, if storage is held constant. If storage is increased, the draft requirement will still increase but not as much as if storage is held constant and the outflows increased.

Surface water of the Uinta Basin originates mainly in the Uinta Mountains north of the Basin and in most cases is considered to be of excellent quality. Very little surface water originates in the lower areas of the Basin, but considerable efforts have been made to develop the water in the lower part of the Basin as it drains from the mountains in the various rivers, creeks and springs.

The ground water (GW) situation in the Uintah Basin deserves special attention. The estimate of 40,000 acre feet per year available for development in the Basin is not considered to be extremely accurate. The exact relationship between surface water and ground water and wetlands is not well defined. Most of the available ground water in the Uintah Basin is close to the surface and is usually of poor quality. The ground water aquifers are shallow and often do not yield substantial amounts of water because of sanding and other pumping problems. In 1965 ground water development was considered negligible but presently it is a major source of municipal and industrial water in the Uinta Basin. Most of this is industrial water developed in the oil fields of the Basin. Some development of ground water has been made for the cities of Duchesne and Altamont. The city of Roosevelt has also developed some ground water sources and is presently engaged in an effort to drill wells to supply a substantial part of the town's water supply. The Johnson Water Association has developed some ground water. A breakdown of surface and groundwater by users in the Uinta Basin is given in Table 8.

Table 8. Water users by source
(acre feet per year, 1973)

User	Surface Water	Ground Water
Vernal	4,815	
Roosevelt	1,817	
Duchesne		580
All other small communities and rural residences including Daggett County	1,378	
Altamont town, Johnson Water Association and Manila		652
Bonanza	369	
Redwash Oil Field		2,173
Ashley Valley Oil Field		4,400
Total	8,379	7,805
Total present water used	16,184	

Each figure in Table 8 is worthy of further explanation. The water use figures for the cities of Vernal, Roosevelt, and Duchesne were taken directly from the master meters of those towns. The figures for all other small communities and rural residences including Daggett County were arrived at by first finding a total population figure and multiplying by an annual per person water consumption coefficient. The coefficient was based on figures of other rural communities which have available water use data. Residents included in this section are those people who live in rural areas where there is no developed water system and either get their water by hauling it from other sources or private house wells. Inasmuch as it cannot be determined how many wells there are or how much water each one is capable of producing and most of the wells are shallow and small, all these wells were considered to draw on surface water sources.[5]

Altamont, Johnson Water Association, and Manila are known to have wells as a water source. The figure for those communities were taken from pages 16-18 of the Uintah Water Resources Study.[6] These pages are reproduced as Table 9 and give a somewhat detailed breakdown of water use by county. The figures in parentheses were arrived at by original research while those figures not in parentheses are based on 1973 population estimates.

The Bonanza figure was taken from the 1972 annual water audit and cross referenced with page 16 of the above mentioned study. It should be pointed out that the figure is a 1972 figure and that it may be somewhat smaller for 1973 as the entire town of Bonanza is a Gilsonite mining town and the operation has scaled down considerably since June of 1973. However, this does not mean that the water consumption of the area has decreased to the same extent. Most of the water used by the firm is in industrial operation and very little is used residentially. Even though many of the residents of the town have moved away because of the

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[5] Bruce Thurston (U.S. Bureau of Reclamation), Carl Carpenter (Central Utah Water Conservancy District), Don Price (U.S. Geological Survey) and Barry Saunders (Department of Natural Resources, Division of Water Resources), "Water Resources: Uintah Resource Study," July, 1973, p. 21-24.

[6] Ibid. p. 16-18

Table 9. Public water supply systems in the Uintah Basin

Water Systems	Estimated Population In 1973	Sources	Firm Amount Availble (CFS)	Number of Connections
Ashley Valley Water System	6,000	Ashley Springs	12.0	2,550 (3,049)
Bonanza (Unincorporated)	170	Infiltration gallery	1.1 (cfs)	36 (16)
Ute Indian Tribe System	1,700	Uriah Heap Spring	3.05	250 (141)
Jensen Water	350	Ashley Valley Water System	Ashley Valley Water System	127 (132)
Lapoint Culinary Water Company	385	Uriah Heap Spring	0.25	70 (103)
Red Wash (Unincorporated	110	Infiltration gallery	3.0	19
Tridell Farmstead Water Co.	175	Whiterocks River	2.0	35 (22)
Whiterocks (Unincorporated	382	Springs	?	? (101)
Maeser Water Impr. District	1,000	Ashley Valley Water System	Ashley Valley Water System	300 (386)
Vernal City	4,000	Ashley Valley Water System	Ashley Valley Water System	2,000 (2,531)[a]
Altamont Town	700	2 Wells	0.5	40 (77)
Duchesne City	2,625	5 Wells	1.51	410 (666)
Hanna (Unincorporated)	105	1 Well	?	6
Myton City	735	Lake Fork River	2.0	112 (193)

Table 9. Continued

Water Systems	Estimated Population in 1973	Source	Firm Amount Available (CFS)	Number of Connections
Neola (Unincorporated)	293	3 Springs	2.0	65 (76)
Roosevelt City	3,773	Uriah Heap Springs	4.0	730 (2,084)[b]
Tabiona Town	350	2 Springs	4.0	50 (97)
Johnson Water Association	550	2 Wells	0.4	250
Manila Town	192	2 Wells Birch Springs	0.13	70 (109)[c]
Dutch John (Unincorporated)	259	Flaming Gorge Reservoir	0.67	90 (139)[c]

[a]Includes Naples.

[b]Includes Ballard and all out-of-city connections.

[c]Based on estimates made by the Utah State University Sociology Department, July, 1973.

Source: Bruce Thurston (U.S. Bureau of Reclamation), Carl Carpenter (Central Utah Water Conservancy District), Don Price (U.S. Geological Survey), and Barry Saunders (Department of Natural Resources, Division of Water Resources), "Water Resources: Uintah Resource Study," July, 1973, p. 16-18.

scaling down of the plant, industrial use has stayed about the same throughout the year of 1973.

Ground water exploration in the Uinta Basin has not been conducted on a large scale. Most aquifers within 200 feet of the surface are near rivers in the central part of the Basin. Due to the low yield ability of these aquifers and quality restrictions, potential development is limited. Wells in these areas range from 50 to 3,000 feet deep and 16 to 24 inches in diameter. The estimated cost is from $24 to $60 per foot of depth and does not include the cost of pumping equipment, roads, powerlines, etc. On the average only 50 percent of the wells in Utah which are drilled in bedrock produce water. This would double the cost of water produced from a well in the Uintah Subregion of HSU7 if the same probability of success holds.

Much of the water produced by the Ashley Oil Field is sold to agriculture although it is industrially produced. In other words, economic returns to water for agricultural use would not justify the development of this water for agricultural purposes only. The water is being sold as a by-product of crude oil exploration and development throughout the Uintah Basin area.

Ground water developed in the process of oil exploration was probably not included in the original estimate of 40,000 acre feet per year available for development because of its extreme depth. The water surveyor probably had some knowledge of the existence of this water but considered it not to be available for development at the time of the survey in 1965. It is very difficult to know the aquifer recharge relationships of any aquifers in bedrock. Because of this, for purposes of this study, all developable water is included in the outflow of the original estimate of 40,000 acre feet per year.

All of the figures in the water budget in Figure 8 have now been considered. These figures outline the present supply and demand situation

Municipal and Industrial water (M & I) use has been broken down into five categories. They are residential, industrial, travel service, commercial and public service. Residential water (RES) is all water used in households. Some of this water is agricultural stock water as the Uinta Basin economy is centered around agriculture, particularly the livestock industry. This stock water was metered with the rest of the household water and could not be separated from the water used for household purposes.

Industrial water (IND) includes all water used in the production of primary goods. There is very little manufacturing in the Uinta Basin. Almost all industrial water is used by the oil industry.

Travel service (TS) including motels, restaurants, resorts and gasoline service stations use very little of the total water used in the Uinta Basin even though tourism is considered to be a major industry in the area.

Commercial water (COM) is used by department stores, grocery stores, oil service companies, etc. Public service water (PS) includes all water used in federal, state, and local government buildings as well as schools, churches, clubs, etc.

All the communities in the Uinta Basin which have public water systems were visited. Water used in each of the five categories of Municipal and Industrial use were recorded from the water records of the systems. Tabulation was made for each use and for all the meter connections in each city. No sampling or statistical analysis was used. The entire population was measured, therefore, each figure represents a population parameter. Those communities which did not have water systems were added to the total by multiplying its population by the water use average of other similar communities.

The figure of 315,000 acre feet per year for wetland requirements (WL) is the inflow necessary to maintain the current water levels in the various wetlands such as marshes and lakes. This requirement is equal to the present evaporation of water plus evapotranspiration by phreatophytes and other water-loving plants.[7]

Agricultural use of water (AG) in the Basin was set at 830,000 acre feet per year with a return flow coefficient of .6288 to surface water. The return flow coefficient to ground water was considered to be negligible.[8]

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[7] John E. Keith, Jay C. Andersen, Calvin G. Clyde, The Economic Efficiency of Inter-Basin Agricultural Water Transfers in Utah: A Mathematical Programming Approach, Utah State University, Utah Water Research Laboratory, Logan, Utah, June, 1973, p. 18.

[8] Alton B. King, Jay C. Andersen, Calvin G. Clyde, Daniel H. Hoggan, Development of Regional Supply Functions and a Least-Cost Model for Allocating Water Resources in Utah: A Parametric Linear Programming Approach, Utah State University, Utah Water Research Laboratory, Logan, Utah, June, 1972, p. 18.

HIGH AND LOW LEVELS OF OIL SHALE DEVELOPMENT

Although the future of the Unita Basin looks bright, many controversial issues are being debated. Some interest groups would like to see development of all water projects in the Unita Basin curtailed. Others would like to see the water resources of the Basin exploited as far as possible. Since many decisions are yet to be made about water resource planning in the Basin, a system of alternatives which approximate the most likely outcomes will be presented.

Estimation of the future water demand situation in the Uinta Basin will be based on the most recent projections. The most important factors affecting the development of water in the Uinta Basin are the plans of the Basin residents regarding certain policies on environmental quality and the need for water development due to population increase. If people of the Basin are extremely conservation minded, it is unlikely that future water development will exceed the available supply. However, if planners decide that certain damages to the environment are minimal and worth the increase in water supply or that development of water resources and industry can be accomplished in such a way as to cause very minimal damage to the environment, then water will become a scarce factor as industrial activity and population increase. In the latter case, water will be bid away from its least productive use and shifted to those uses which give higher returns. At the present time agriculture probably yields the lowest return to water of any use in the Basin, and some farmers will probably not be able to pay a much higher price for irrigation water. However, with world demand for food increasing each year, it might well be that the return to water from agriculture will be much higher in the future. In any case, the price of water must fall within the farmers cost structure or water will be bid away to those users which can afford to pay the higher price.

Therefore, such factors as environmental awareness, completion of the Central Utah Project, development of oil shale, and other energy resources of the Uinta Basin will all have an effect on public plans for the future of the Basin.

At present most water systems, especially city water systems, are functioning at capacity. This could have the effect of causing the residents of the area to think that there is already a water shortage in the Basin. At the present time, the Basin as a hydrologic unit produces water in excess of in-Basin consumption. Even though most city water systems are functioning at capacity, developable water is still available. The purpose of this part of the study is to find out when or if in-Basin water demands will exceed the developable supply.

Oil Shale Development

Oil shale industries have been established in many foreign countries and exist presently in Mainland China and the USSR.[1] The exact capabilities of oil shale development in the U.S. are not well known. The state of technology and experimental work with these technologies are presently not developed to the point where commercial production is

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[1] U.S. Bureau of Reclamation, Department of the Interior, Final Environmental Statement for the Prototype Oil Shale Leasing Program (2400-00785), Vol. 1, Washington, D.C., March 1973, p. 1-4.

considered to be feasible in the U.S. The map in Figure 2 shows the areas of Utah most likely to receive extensive oil shale development.

Two major technologies have been advanced concerning the development of oil shale in Utah. These are: (1) mining followed by surface processing, and (2) in-situ (in-place) processing. The in-situ process is not sufficiently developed at the present time to be put into commercial production.[2] Recent energy and oil shortages have caused much increased interest in this process, and it is likely that many research efforts will pursue this method in the future.

Mining has advanced under two systems--open-pit or strip mining, and room-and-pillar mining. (See Figures 9, 10 and 11 for explanation of the different mining methods.)

Open-pit or strip mining is detrimental to the natural environment and is not considered to lend itself readily to use in the Uinta Basin due to the depth of the oil shale and attendant environmental problems. The room-and-pillar method involves extracting shale from beneath the surface leaving large chasms or rooms with shale rock pillars at specified places in the room to support the ceiling. Shale is taken from the mine and moved to a processing plant where crude oil is removed from the oil bearing rock. After oil has been removed by a retorting process, oil spent rock is compressed into large bricks and taken back into the mine room, thus filling the mine with oil spent rock. Spent shale is only 88 percent compressable to its original density leaving 12 percent to be disposed of in some other way. The rock could be placed

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[2] Ibid, p. 1-5

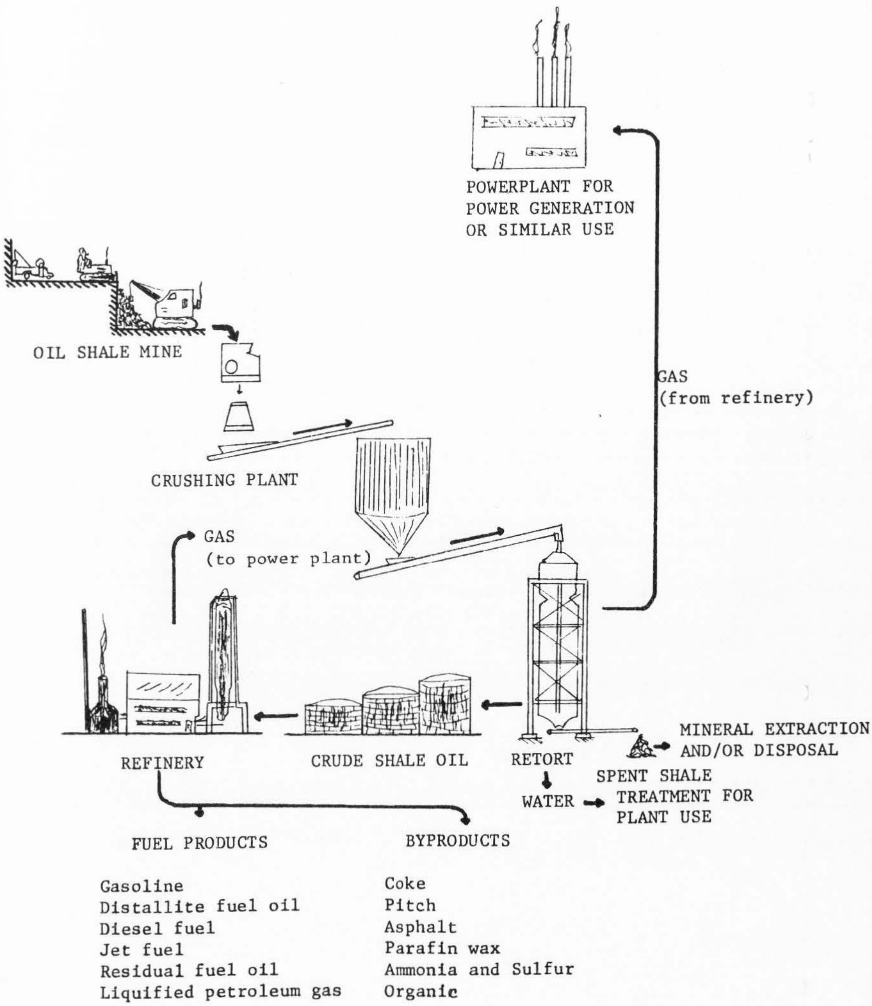
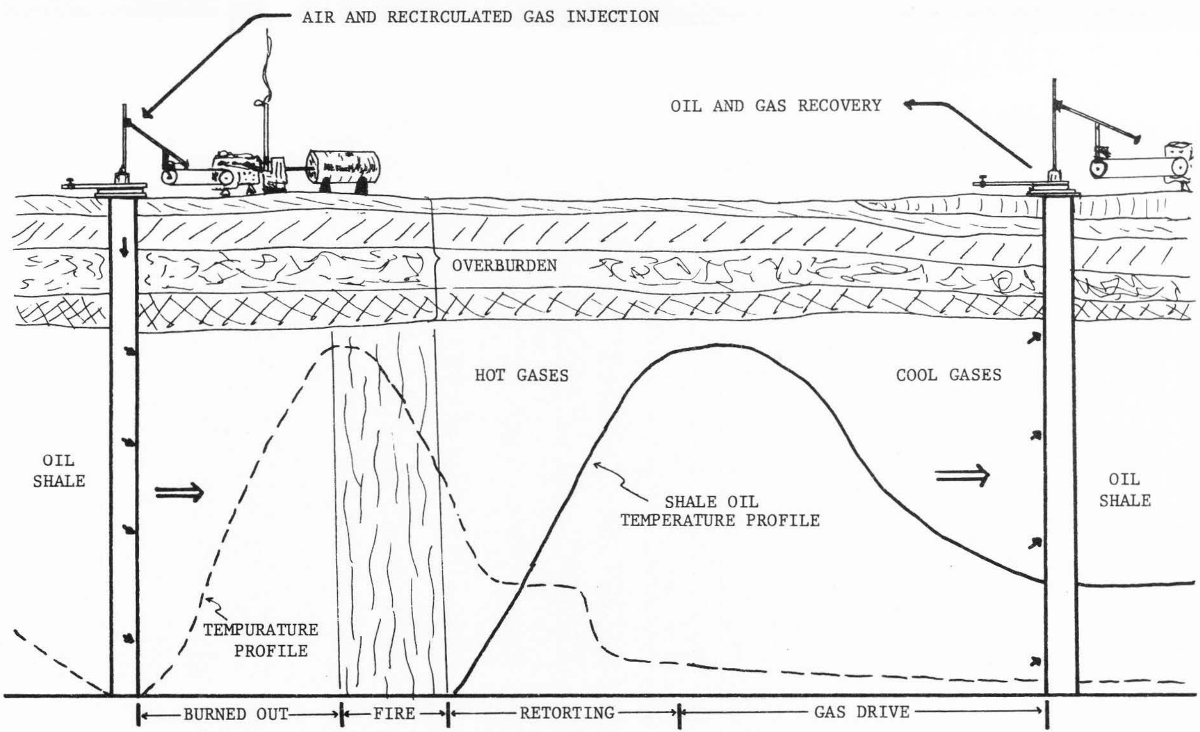


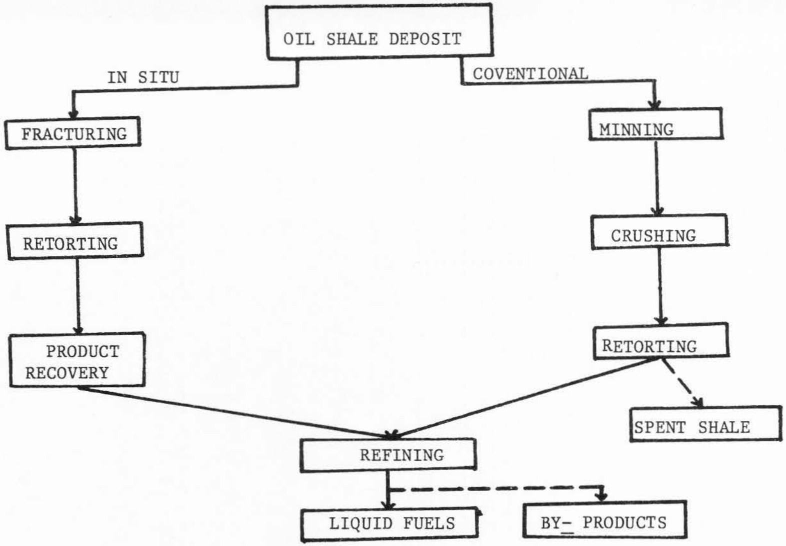
Figure 9. Schematic diagram of oil shale surface mining

Source: U.S. Bureau of Reclamation, Department of the Interior, Final Environmental Statement for the Prototype Oil Shale Leasing Program (2400-00785), vol. 1, Washington D.C., March 1973, p. 3,4.



Source: U.S. Bureau of Reclamation, Dept. of the Interior, Final Environmental Statement for the Prototype Oil Shale Leasing Program (2400-00785), vol. 1, Washington D.C. March 1973, p. 3, 4.

Figure 10: Schematic representation of a In Situ retorting operation.



Source: Environmental Statement, pp. I-6

Figure 11: Schematic comparison of In Situ and Conventional retort

in gullies to prevent erosion or other environmental damage. The rest of the spent shale will be disposed of in a manner which will minimize environmental disturbance.[3]

The in-situ process is a lesser developed technology, but is receiving more and more attention as the price of oil increases and the demand for water continues to grow. The in-situ process (Figure 13) involves pumping hot gasses into the ground causing the shale to fracture and melt out the oil. Once the oil is melted out of the shale, it can be pumped to the surface. This process requires about three to five well holes per acre, and is quite detrimental to the environment, but the environmental damages can be corrected in a shorter time than those caused by open-pit mining. One main advantage of the in-situ process is that it uses considerably less water than other methods. (See Table 8) Figure 14 shows a diagramatic comparison of the two processes.[4]

Water is an inherent by-product of oil shale retorting. It may be produced at a rate as high as 10 gallons per ton of shale retorted, but more typically will range from 2 to 5 gallons per ton. Water requirements for the two processes are given in Table 10.[5]

The water processing requirements of the different methods being considered are given in Table 11.[6]

As can be seen, the in-situ process uses much less water, but the

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[3]Ibid, p. I-8-I-20.

[4]Ibid, p. I-34-I-39.

[5]Ibid, p. III-60.

[6]Ibid, p. III-34

		Thousands of Acre Feet							
		Underground Mine; 50,000 Bbls/day				Surface Mine; 100,000 Bbls/day			
		Water Requirements[2]	Water Produced[3]	Excess Water	Diverted Water	Water Requirements[2]	Water Produced[4]	Excess Water	Divert Water
Process Requirement	High quality Water	75-127	175	60-100	0-12	151-234	175	25-46	22-58
	Low quality Water	88-133	373	240-285		178-266	373	107-195	
	Subtotal	163-260							
Associated Urban	High quality Water	20-27			20-27	34-45			34-45
Total		184-287	548	300-385	20-29	363-545	548	132-241	56-103

1. Water requirements and produced water based on a 30-year period.

2. This would represent the maximum divered surface water requirements should no water be available from processing or mines.

3. Assumes a maximum pumping rate of 40 cfs declining to 18 cfs in the 30th year.

4. Assumes a maximum initial pumping rate of 30 cfs declining to 18 cfs in the 30th year.

Table 10. Thirty year cummulative demand-supply water balance 1/

process may not become commercially feasible until 1980 unless research is much accelerated from the present level.

With this brief explanation of existing technologies, the approximate time at which water will become scarce in the Uinta Basin can be estimated.

All the water use figures in the Final Environmental Statement for the Prototype Oil Shale Leasing Program are based on a 1,000,000 barrels per day industry. The industry will begin with a 400,000 barrels per day prototype, and is expected to expand to the 1,000,000 barrels per day prototype by about 1985. However, the industry will not reach the 1,000,000 barrels per day prototype unless federal lands are leased to oil developers. [7]

It can be seen that Utah's share of a 400,000 barrels per day industry would be approximately 60,000 barrels per day. This would support one 50,000 barrels per day plant as outlined in the Final Environmental Statement for the Prototype Oil Shale Leasing Program. If federal lands do become available in 1985 then another 100,000 barrels per day plant could be introduced. In that case, Utah would be producing about 15 percent of the 1,000,000 barrels per day prototype. It is estimated that the mature industry could reach 2,500,000 barrels per day some time after the year 2000. This would indicate that the Utah industry could expand with enough plants to produce another 225,000 barrels per day totalling about 375,000 barrels per day.

The 50,000 barrels per day plant will be considered the low level of development. This case will be presented as though only on a 50,000

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[7] Ibid, p. III-6

barrel per day plant were feasible and no other plants were to be built in Utah. The high level of oil shale development case will be considered to be the additional 100,000 barrels per day plant which sould be introduced in 1985.

Table 11. Water consumed for various rates of oil shale development (acre feet per year)

Process reuqirements	50,000 bpd underground	100,000 surface mine	50,000 bpd in-situ
Mining and crushing	370-510	730-1,020	--------
Retorting	580-730	1,170-1,460	--------
Shale oil upgrading	1,460-2,190	2,920-4,380	1,460-2,220
Processed shale disposal	2,900-4,400	5,840-8,750	--------
Power requirements	730-1,020	1,460-2,040	730-1,820
Revegetation	0-700	0-700	0-700
Sanitary use	20-50	30-70	20-40
Subtotal	6,060-0,600	12,150-18,420	2,210-4,780

The construction of a 50,000 barrels per day plant will employ about 1,470 construction employees for the plant and an additional 696 more construction employees involved in urban construction.[8]

[8] Ibid, p. III-245.

It will take about three years to build the plant. Once the plant is in operation, it will employ 1,293 permanent employees. Construction of the plant will begin in 1975. The effect on water use of this plant is given in Table 11. Table 13 illustrates expected employment during the development period.

Table 12 shows the increase in water demand in acre feet per year that would occur if oil shale were to be developed in the Uintah Basin. To build either a 50,000 barrels per day plant or a 100,000 barrels per day plant, will take three years. Once the plant is built, most construction workers will move on and be replaced by permanent plant employees. To estimate total new jobs, either the total construction workers or the total permanent employees figure was multiplied by an employment multiplier of 3.2.[9]

This means that there would be a total of 3.2 new jobs introduced into the economy for each new job in a base industry. If a labor participation rate of 1.2 employed people per household is used, it can be seen that each new job in base industry will produce 2.56 new households in the Basin economy once existing unemployment is absorbed. The average family size of Uintah Basin families is about 3.65 people. If it is assumed that the average new family will be somewhat smaller, say 3.0 people, then each new job in base industry will increase the Basin population about 7.68 people.

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[9]Nureddin A. Taqieddin, Evaluation of the Impact of Federal Participation on the Redistribution of Economic Activity and Population in the State of Utah, Doctoral Dissertation, Utah State University, Logan, Utah, 1973, p. 46.

Table 12. Water use breakdown for high and low oil shale development in the Uintah Basin (acre feet per year)

	Low Development 50,000 bpd Plant		High Development 100,000 bpd Plant & 50,000 bpd Plant		In-Situ Plants of 150,000 bpd
	First 3 years	Full Plant Operation	First 3 years	Full Plant Operation	Full Plant Operation
Increase in Residential Water Demand*	6,487	3,873	12,975	8,908	8,908
Increase in Industrial Water Demand	65	7,769	7,769	15,538	39,128
Increase in Travel Services Water Demand	324	194	649	446	446
Increase in Commercial Water Demand	843	503	1,686	1,158	1,158
Increase in Public Service Water Demand	778	465	1,556	1,068	1,068
Total Increase	8,497	12,803	24,636	27,118	15,493

*Assumes 1.2 employed persons per household and water consumption of 1.17 acre feet per year per household.

The employment multiplier of 3.2 is based on recent figures for counties in Utah which have undergone similar development periods. Historically, the multiplier of the Basin counties has been much lower than 3.2. The higher figure was used because the employment multiplier

Table 13. Employment breakdown for high and low oil shale development in the Uintah Basin

	Low Development 50,000 bpd Plant		High Development 100,000 bpd Plant & 50,000 bpd Plant	
	First 3 years	Full Plant Operation	First 3 yrs. on 100,000 bpd Plant	Full Plant Operation of Both Plants
Plant Construction Jobs	1,470		2,940	
Urban Construction Jobs	696		1,392	
Total Construction Jobs	2,166		4,332	
Three-year Temporary Jobs	5,545		10,090	
Permanent Plant Jobs		1,293		2,974
Total New Permanent Jobs		3,310		7,613
Increase in Water Demanded		3,873 ac. ft./yr.		8,907 ac. ft./yr.

is based on the complexity of an economy. The advent of oil, oil shale, and possibly other industries will cause the Basin economy to shift away from the historically agrarian to a more complex industrial economic structure.

Multiplication of the new jobs introduced into the base industry of an area by the employment multiplier will give the number of new jobs which will enter an area as a result of new jobs in a base industry. In the case of the Basin, some of the new jobs introduced will be for temporary workers only while after the plants are built the jobs introduced will be permanent.

The average household in the Uintah Basin uses about 1.17 acre feet of water per year, which multiplied by the total number of new households gives the increased water demand in the residential sector. Figures for the total increase of water use in the travel services, commercial and public service sectors are based on the increase in population that would arise due to oil shale development. The industrial figure does not increase significantly until the plant is in operation because the alternative does not assume any increase in any other industry.

Figures for high oil shale development were arrived at by the same means as for the 50,000 barrels per day plant. The alternative assumes that one 50,000 barrels per day plant is already operating and that another 100,000 barrels per day plant is added making total production in the Basin area 150,000 barrels per day. This 150,000 barrels per day represents about 15 percent of the 1,000,000 barrel per day industry that could develop in the tri-state area (Utah, Wyoming, and Colorado) if the oil shale prototype leasing program is followed. It is estimated that 15 percent of the high quality reserves in the tri-state area are located in Utah.

The figures in the Final Environmental Statement for the Prototype Oil Shale Leasing Program have been based on the construction of one

50,000 barrels per day plant in the Uinta Basin.[10] If this is in fact the case, oil shale development will not threaten the water supply in the Basin, but at the time of the study the development of oil shale was considered to be a marginal operation with the price of oil at \$3.90 per barrel.[11] The price of crude oil has since risen to over \$10.00 per barrel in recent months. The price may not always stay at this high level, but will probably always be higher than \$3.90 per barrel. With an increased level of economic incentive oil shale development will become a much more lucrative business.

The Department of Interior estimates that there is approximately 107,000 acre feet per year of water available for oil shale development in the Uinta Basin.[12] An oil shale industry producing 350,000 barrels per day would have to be introduced into the Basin in order to use all of this 107,000 acre feet per year if all other industry is held at present levels. According to the Department of Interior the area will not support an industry this heavy with the present state of technology.[13]

If an in-situ plant was introduced at full capacity of 150,000 barrels per day, it would use much less water than a 150,000 barrels per day mining operation as can be seen from Table 10.

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[10] U.S. Bureau of Reclamation, Department of the Interior, Final Environmental Statement for the Prototype Oil Shale Leasing Program (2400-0785), Vol. 1, prepared in compliance with Section 102 (2) (c) of the National Environmental Policy Act of 1969, Washington, D.C., March, 1973, p. I-4.

[11] Ibid, p. III-4.

[12] Ibid, p. II-27.

[13] Ibid, p. III-5-III-8.

Before the introduction of the current oil boom, the population in the Basin grew at about .36 percent per year or about 72.5 new households per year up to 1970.[14] The population since 1970 has increased 5.3 percent in 1971; 13.7 percent in 1972; and 18.5 percent in 1973. (See Table I in Chapter I.) Uintah Basin population increases have averaged 12.5 percent per year from 1971 to 1973. It could be reasonably expected that the Uintah Basin population will continue to grow at a high rate until about 1985, the time when oil shale development might peak out. After that, the population will probably grow at a more normal rate for a community the size of the Unitah Basin.

If Utah is charged for one-half the Mexican Treaty water, only 76,000 acre feet per year of water will be available for development. If oil shale reaches the highest level of development and no attendant industry is introduced, there will be a water shortage whenever water use attendant to the oil shale industry increases water demand 44,000 acre feet per year. If Utah is not charged for one-half the Mexican Treaty amount and there is no other attendant development in any other industry, it appears that the 237,000 acre feet per year available will be sufficient for future needs.

If the following conditions are met, there will be enough water to provide for in-Basin needs for the forseeable future.

1) All other primary industry will remain constant except oil shale.

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[14] Office of the State Planning Coordinator, "Phase III Report: Population and Employment Implications of the Alternative Futures," August, 1972, p. 26, Exhibit 9F.

2) The population will show a normal rate of net growth rather than a net out-migration.

3) The Bonneville Unit will be completed.

4) Utah will not have to supply half the Mexican Treaty charge.

5) The oil shale industry will not exceed the 1,000,000 barrels per day prototype within a reasonable time.

As recorded on Table 3 in Chapter I, Utah will have 76,000 acre feet per year of water available for development if charged for one-half the Mexican Treaty water. Table 8 in Chapter III points out that a high level of oil shale development will need 33,898 acre feet per year more water than is presently being used. If Utah does not have to provide the Mexican Treaty water, 237,000 acre feet per year will be available.

If 237,000 acre feet per year were available, the water needs of oil shale development can be met quite easily. Increased demand due to other industrial development will undoubtedly occur and thus use more of the remaining water. This possibility is discussed in detail in the next chapter. Even if the Upper Basin does not supply half of the Mexican Treaty charge, there is still not enough water available to provide for an inter-basin transfer of 390,000 acre feet per year required by the Ute Indian Unit of the Central Utah Project. (See Appendix A.)

The mature oil shale industry could reach a capacity of 2,500,000 barrels per day. An industry of this size would require an additional 118,000 acre feet per year of water. This would increase the total population of the Basin to about 112,972 people. Due to natural population increases, these people would require an additional 3,965 acre feet of water each year. About 20 years after the 2,500,000 barrels per day industry was reached there could be a water shortage unless there once again becomes an out-migration situation in the Basin.

Summary

If (1) oil shale development reaches 2,500,000 barrels per day, and if (2) all other primary industry remained constant, and if (3) only the Bonneville Unit of the Central Utah Project is completed, and if (4) Utah is not charged with half the Mexican Treaty water, there would yet be undeveloped water in the Uintah Basin. Water could still be scarce at some points in the Dasin, but there would be undeveloped water available somewhere until normal population increases used up all the excess supply.

HIGH AND LOW LEVELS OF ATTENDANT INDUSTRY

To consider high and low levels of industries other than oil shale, but in addition to an oil shale industry, requires that the various water consuming industries be listed. Once the specific industries have been listed, then high and low levels of each industry will be described and water use for each level be computed.

Only those industries that appear to have the greatest potential for development will be considered. It is difficult to say which industries will be present 20 or 30 years from now. New industries which are not considered to be worthwhile now could be introduced, and industries which may be doing well at the present time may fail due to unforeseen circumstances in the future. The industries which appear to merit further development are:

1) Agriculture
2) Crude oil and natural gas
3) Phosphate
4) Gilsonite, nacholite, and other minerals
5) Recreation

Agriculture

There will undoubtedly be at least some further development of agriculture in the Uintah Basin. In September of 1965 the Ute Indian tribe agreed to defer the development of 14,242 acres of their land to not later than the year 2005. This arrangement with the Bureau of Reclamation by the Ute Indian Tribe to allow for the full development of the Bonneville Unit of the Central Utah Project. The Ute Indian Unit of the Central Utah Project is designed to return the water borrowed from the Indians for the Bonneville Unit.[1] Development of the Indian agricultural land is the minimum that can be expected, any further development is likely as increased demands may make agriculture increasingly more lucrative in the future. Water for the development of 26,000 acres of Indian land has already been set aside. The water for this land amounts to about 56,968 acre feet per year. At least 56,968 acre feet per year now and supplemental irrigation water will be developed for use in the Basin. Since this is the minimum agricultural water development that could occur, 56,968 acre feet per year will be the figure representing the low level of agricultural water development that could occur, 56,968 acre feet per year will be the figure representing the low level of agricultural development.

The future of agriculture in the Basin is somewhat precarious. The Ute Indian Unit which was to provide 268,000 acre feet per year of irrigation water is presently pending congressional approval.[2] At present, there does not appear to be sufficient support to fund the construction of the Ute Indian Unit. There is also much debate concerning the Bonneville Unit. The Bonneville Unit is designed to provide an additional 277,000 acre feet per year for irrigation purposes.[3]

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[1]U.S. Bureau of Reclamation, Department of the Interior, "Summary Sheets of the Units of the Central Utah Project," 1973, Ute Indian Unit, p. 2.

[2]See Appendix A.

[3]See Appendix A.

If the Bonneville Unit is completed much of this water will be used for municipal and industrial purposes rather than for agriculture.

To arrive at a maximum development for agriculture, a summary of the proposed development of the Central Utah Project will be used. Table 11 shows water to be developed for agricultural uses by each unit of the Central Utah Project. (For detailed water breakdown, see Appendix A.)

It is very unlikely that all this water will be developed for agricultural purposes even if the Central Utah Project is completed. However, the total figure in Table 14 will be used as the upper limit of agricultural water demands on the potential water supply in the Uinta Basin.

Crude Oil and Natural Gas

There are already many crude oil and natural gas wells in the Uinta Basin. A summary of production is given on Table 15.

Water requirements for the oil industry alone are not determinable. Most oil fields produce much more water than they use. It is generally expected that this circumstance will not continue because the major area of drilling has shifted away from the Ashley Valley Oil Field to the Altamont-Bluebell field. Ground water is much less plentiful in this area. In any case, some water will be produced with oil and natural gas. Therefore, it has been assumed that the oil drilling and exploration part of the crude oil and natural gas industries in the Uinta Basin will produce enough water to be self-sufficient. However, if a crude oil refinery is located in the Basin, demand for water will significantly increase. To determine the amounts of water required by an oil or gas refinery, refinery operators in Salt Lake County were interviewed.

Table 14. Irrigation water to be developed by the Central Utah Project in the Uintah Basin (acre feet per year)

	In-Basin Development	Out-of-Basin Development
Bonneville Unit	27,800	202,200
Jensen Unit	4,700	
Uintah Unit	52,000	
Upalco Unit	20,500	
Ute Indian Unit	75,000	211,000
Total	180,000	413,000
Total Water to be developed		593,200

Table 15. Crude oil and natural gas production in the Uintah Basin in 1971

County	Oil (Barrels)	Gas (Mcf)
Daggett	6,000	3,231,000
Duchesne	2,886,000	2,197,000
Uintah	6,041,000	13,113,000
Total	8,933,000	18,541,000

The chief process engineer for the Salt Lake Phillips 66 refinery has found that about one barrel or 42 gallons of water are required to process 10 barrels of oil.[4] This is about 10 percent of the crude throughput of the refinery. Personnel requirements for a big refinery are about the same as for a small refinery. Even though plant operation personnel stay about the same, sales and marketing personnel increase slightly with the size of the plant.

The manager of the Chevron Oil refinery in Salt Lake City formulated what he thought a hypothetical refinery which could be supported by fields the size of those in the Uinta Basin. He estimated this refinery would have an average daily through-put of 70,000 barrels per day.[5] He assumed a fully integrated refinery which produced a full line of finished products in proportion to the demand for these products and that its parent organization would furnish marketing and accounting services. A plant of this size would require 120 to 150 people for operation and would use about 7,670 acre feet of water per year if a once through system was used until the price of water became prohibitive. As the price of water increases, more and more air cooling is used and more recycling would allow the refinery to get by with using less water. The absolute minimum water requirement would be about 8 to 10 percent of the crude through-put. For a refinery of this size, a minimum of about 317 to 329 acre feet per year would be required. It is unlikely that a refinery could make sufficient investment to merit recycling at the onset of operation and find it economically feasible.

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[4] Interview with Ralph Cawley, Chief Process Engineer, Phillips 66, Salt Lake City, Utah.

[5] Interview with Richard Coulter, General Manager, Chevron Oil Refinery, Salt Lake City, Utah.

From the figures above it can be seen that if an oil refinery were to be introduced into the Uinta Basin the most likely consumption of water would range from 8,000 to 8,100 acre feet per year. These figures are based on the same employment, population, and water use per household, expansion coefficients used for the oil shale retorting plant of Chapter III.

One gas line leading from the Basin already exists, and plans are presently underway for another to be built in 1974. The present gas line goes west to the Wasatch Front markets, whereas the new pipeline will go east to Colorado markets. This will expand the marketability of Uinta Basin produced natural gas. Natural gas is also produced with oil and has to be extracted from the crude oil before it can enter the pipeline. Crude oil cannot enter a pipeline unless the natural gas is either flared off or is extracted by a gas refinery.

There will be a gas refinery built at Ioka.[6] The refinery will employ about 600 people. Water use associated with 600 people will be about 1,666 acre feet per year. The plant will use about 2,500 acre feet per year at the most. Water consumption of a natural gas refinery can be reduced to almost zero. The introduction of a gas refinery into the Uinta Basin will increase water use between 1,666 and 4,166 acre feet per year to take care of the refinery and the additional jobs and population required.

Phosphate

Phosphate deposits in the Uinta Basin area have been mined on a

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[6] Jack R. Curtsinger, "Impact of the Oil Industry on the Uintah Basin," Division Manager of Gas Producing Enterprises, Inc., written communication to Uintah Council of Governments, February 16, 1972.

commercial basis since 1961. Practically all of this mining is done by one chemical company at a single site on Big Brush Creek. The method of extraction is strip mining. After mining, the material is pulverized at a plant adjacent to the mine pit. Output has been increasing over the last few years. One of the major constraints to the industry is the water supply.[7] The present water supply is a system of springs located near the mining site. These springs are the major if not the only source of water as well as the source for Big Brush Creek which flows from the springs through the plant and eventually into the Green River.

Major uses of the water in the operation are for drilling and dust control in the mine. Sediment ponds are maintained on the site, but some water is released into the Green River through the constant flow of Big Brush Creek. The flow into the Green River and eventually the Colorado has caused some concern in the area. The flow may be a contributor to the high level of dissolved solids in the Colorado River. The high level of dissolved solids in the Colorado River may render the water unfit for agricultural and culinary use down stream.[8]

Water produced by the springs is not readily accessible. However, it is known that the Jensen Unit of the Central Utah Project is to provide an additional 7,200 acre feet per year of water to the company by means of a pumping plant some four miles above Tyzack Reservoir in

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[7] Mark H. Horne, "Uintah Basin Study," Department of Natural Resources, Division of Water Resources, January, 1973. Mineral Development, p. 3.

[8] U.S. Bureau of Reclamation, Department of the Interior, <u>Final Environmental Statement for the Prototype Oil Shale Leasing Program</u> (2400-0785), vol. 1, 1973, p. 11-32.

Duchesne County.[9]

One-third of the total amount of water to be developed by the unit will go to the phosphate company. This will amount to one-half the water developed by the first stage of the Jensen Unit. The unit will be developed in two stages. The first is to provide the phosphate industry with 7,200 acre feet per year, and 4,700 acre feet per year for irrigation purposes. The second is to provide the immediate area with up to 10,800 acre feet per year of municipal water. The irrigation part of the first stage and the whole second stage are to be developed only if additional water is required for irrigation and municipal use in the area.[10]

Other Minerals

Other minerals of the area including gilsonite, nacholite, tar sands, and some others are economically worthy of development. Gilsonite is an industry which has long been developed in the Unita Basin. The industry is reducing its production due to engineering problems and the fact that the economically developable veins are running out. The water use of the industry was discussed in Chapter II in connection with the town of Bonanza. The industry will cause no increase in water use in the future, and it may possibly decline.

Nacholite, tar sands, and other mineral industries in the Uinta Basin are either developed in conjunction with some other mineral or are not considered to be economically worthy of development at the present

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[9]U.S. Bureau of Reclamation, Department of the Interior, "Summary Sheets of the Units of the Central Utah Project," 1973, Jensen Unit, p. 1.

[10]*Ibid*, p. 2

time.

Recreation

The recreation industry is a major industry in the Basin, but is a small water user as can be seen by the schematic water budget shown on p. 43. The industry is expected to level off or decline so it will not be included further in the analysis. Table 16 presents the summary figures for those futures considered significant. This table also shows that 646,553 acre feet per year more water will be needed to satisfy a high level of industrial development. As shown in Table 7, on page 47, only 237,000 acre feet per year is available for further development if Utah does not supply half the Mexican Treaty charge. Only 75,000 acre feet per year is available if Utah does not have to supply half the charge. Basin residents will not have a water shortage if the charge is not called for and only the low level of development is reached.

They will find themselves short of water if the high level of development is reached even if they are not charged for the Mexican Treaty water. The high level alternative will increase water demand 646,553 acre feet per year. Developable water to meed this demand is 237,000 acre feet per year (uncommitted supply, as seen in Table 7), 27,800 acre feet per year (water developed by the Bonneville Unit for in-Basin use, see Appendix A), and 56,968 acre feet per year for supplemental and new irrigation water to be deferred Indian lands in the Basin. Therefore, the total amount of water available to satisfy the needs of the high level alternative is 321,768, a deficit of 324,785.

Table 16. Summary of development alternatives

	Increase in Water Use (ac. feet per year)	
Alternative	High Level	Low Level
Oil Shale	33,898	16,000
Crude Oil	8,089	8,006
Natural Gas	4,166	1,666
Agriculture	593,200	56,968
Phosphate	7,200	7,200
Total	646,553	89,840
Total without agriculture	53,353	32,872

Agricultural development requires the biggest part of the high level of development. water. Agriculture will also be the water use which receives the lowest return to water as a factor of production. In other words, if the price of water increases, water will be bid away from agriculture to other uses which have a higher return to water. The agricultural demand for the high level alternative is 593,200 acre feet per year, but there is a deficit of 324,785 acre feet per year which agriculture must stand. This means that even though agriculture will want 593,200 acre feet per year, only 268,415 acre feet per year will be available. If agriculture cannot get all the water needed, the industry will not develop to the desired level or will find a way to make the water that is available go further. Some water development alternatives are discussed briefly in the last section of this thesis.

Agricultural development in the Basin could reach the high level if no other water was diverted out of the Basin. Only 180,000 acre feet per year are needed to reach the level of in-Basin agricultural development proposed by the Central Utah Project. To accomplish this, 268,415 acre feet per year is available if no inter-Basin transfers take water out of the Basin. However, if only the Bonneville Unit is completed, Uintah Basin agriculture will still be facing a deficit of 48,185 acre feet per year. The Ute Indian Unit proposes an import of 10,000 acre feet per year from Flaming Gorge Reservoir. If only the Bonneville Unit is completed, the deficit will be increased to 58,185 acre feet per year.

WATER DEVELOPMENT ALTERNATIVES

In times past there have been great water development plans which ranged from melting polar ice caps to desalting sea water. Many plans have been put aside because most of our water needs can be met by accomplishments on a less grand scale. Usually, it has been found on close examination of water management practices that if efficiency were increased, the already available water supply will go much further. Still, a time may come when the trade off between efficiency and increased supply will favor further source development. To increase efficiency is not always easy and is seldom free.

Some areas of the state of Utah have reached this point. The Wasatch Front area of the State has been a large water user while the Uinta Basin has been a surplus water producing area historically. Because of the greater need for water in the Wasatch Front area, the Central Utah Project was conceived to transfer water from the water "rich" Uinta Basin area. As noted in Chapter I, proposed exports amount to some 627,600 acre feet per year. The only unit of the Central Utah Project which proposes to transport water into the Basin is the Ute Indian Unit. This Unit is to provide about 10,000 acre feet per year to the phosphate industry and some supplemental irrigation water. The same unit proposes to divert 390,000 acre feet per year from the Basin leaving about a 617,000 acre feet per year net loss of water from the Basin to other areas in the State.

The purpose of this chapter is to discuss some of the alternatives available to residents of the Basin for increasing or supplementing their present water supply. All the alternatives do have economic implications, but it is beyond the scope of this study to present the details of all these implications. The presentation of these alternatives will offer some guidance as to what is available as supplemental water supply sources.

Studies have been made in recent years which indicate that water supplies can be increased by application of certain water management alternatives. A list of some possible alternatives which show promise in the Uinta Basin would include the following:

1) Control of water-loving plants.

2) Weather modification.

3) Watershed management.

4) Evaporation supression.

Control of Water-Loving Plants

Phreatophyte plants are located along river banks and in lowlands where a continual source of water is available to the root systems. The most common species found in the Uinta Basin are cottonwood, salt cedar, willow, and greasewood. These species generally have high consumptive use of water and account for about 40 percent of the phreatophytes in the Basin. About 375,000 acre feet per year is lost by the evapotranspiration of these plants.

In river bed areas, 13,000 to 16,000 acres of these plants could be eradicated. Based on an annual consumption of 1.5 to 2.0 acre feet per year, stream flow could be increased from 30,000 to 50,000 acre feet per year. However, the ecological consequences of such action must be determined before eradication is undertaken.

The economic implications of phreatophyte eradication are many. The total cost of removing the plants, including environmental damage, may not be more than the value of the additional water. Monetary costs of such an undertaking would be high not to mention the hard-to-measure costs of environmental damage. Conservationists' attitude at present would probably be to oppose the idea, but if the water is badly needed, the supply can be increased substantially by this method.[1]

Weather Modification

Studies and experiments by the U.S. Bureau of Reclamation and others have established that, through various cloud seeding techniques, it is possible to increase precipitation. As techniques are perfected so that time, location, and quantity of the increase can be better controlled, weather control might be a source of supplementary water in the Uinta Basin. If runoff from the Uinta Mountains could be increased 10 percent, this would add another 100,000 acre feet per year to the Basin supply. Although the numbers are only speculative, the potential is becoming more real each year.[2]

Watershed Management

Various experiments have been conducted to determine the effect of management on the amount of runoff occurring from a watershed. Several studies in the Upper Colorado River Basin have demonstrated that the

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[1] Lloyd H. Austin, Water Management Alternatives in the Uintah Basin, Utah State University, Logan, Utah, 1970, p. 105-106.

[2] Ibid, p. 107.

possibility of water yield improvement through watershed management techniques could supplement the water supply. This alternative offers great potential, but much more research needs to be done.[3]

Evaporation Suppression

Reduction of evaporation from reservoirs in the Uinta Basin offers some possibilities for saving water. The estimated mean annual evaporation loss from the enlarged Strawberry reservoir is about 26,400 acre feet, 5,700 acre feet from Starvation Reservoir, and about 7,900 acre feet for the rest of the major reservoirs in the area. By using evaporation suppressants losses could be reduced up to 50 percent amounting to some 20,000 acre feet per year. If applied to the ultimate phase of the Central Utah Project, this method could save up to 40,000 acre feet per year.[4]

Although all of the above alternatives have some promise, economics dictate that the cost of these supplemental water sources must fall within the users cost structure.

Summary and Conclusions

The Uinta Basin as a major water producing area has received much attention as a potential water source for the more arid parts of the State. For this reason, the Central Utah Project was conceived. The Project provides for heavy water transfers out of the Basin. Recent

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[3] *Ibid.* p. 108.

[4] *Ibid.*

increases in the demand for minerals located in the Basin has caused the in-Basin demand for water to increase more rapidly than thought by those who proposed these extensive transfers. Even though it is known that in-Basin water demand is rapidly increasing, it is not known how long this can be expected to continue or if it will continue long enough to cause an in-Basin water shortage. The purpose of this study is to answer these unknowns by first evaluating the present supply and demand situation in the Basin, and then making the relevant projections which will determine the future water situation.

Three general conclusions have been derived:

1) In-Basin water needs can be met if only the conditions for the low level of development are accomplished. It does not matter whether Utah is charged for the Mexican Treaty water. If congressionally approved units of the Central Utah Project are completed, there would be enough water to satisfy a low level of economic development;

2) In-Basin water demand will exceed the supply if a high level of economic development is attained regardless of whether Utah is charged for half the Mexican Treaty water. If Utah is charged for the Mexican Treaty water, there will be a shortage of about 570,553 acre feet per year by 1985. Agriculture would be the main source for water to satisfy increased industrial demands. If Utah receives the Mexican Treaty charge, only 21,647 acre feet per year will be available for agricultural development in the face of a demand for 593,200 acre feet per year. This is based on the assumption that agricultural water will be treated as the lowest use. This amount of water will not even satisfy the irrigation requirement for the federally deferred Indian lands.

If Utah is not charged for the Mexican Treaty water, agriculture will still not have enough water to reach the high development level unless supplemental water is introduced. However, in this case, the amount available to agriculture will be 161,000 acre feet per year more, but the deficit will still amount over 300,000 acre feet per year;

3) The most important conclusion of this study is that only 233,353 acre feet per year is needed to satisfy the in-Basin needs of the high level of development alternative. The in- Basin water requirement for the high level of economic development is 180,000 acre feet for agriculture, and 53,353 acre feet for industrial development. The shortage of agricultural water will be in other basins if enough water is kept in the Uinta Basin.

Even though this study has been based on the most recent and complete information available, certain subject areas have not been developed well enough to permit projections based on these areas to be accurate as could be if more research were completed. The employment multiplier used is not based on research conducted in the area of the study, but rather on areas which are considered to have undergone economic development similar to that which is predicted for the Uinta Basin.

The information available on ground water for the study area is not complete. Further study in this area would allow sound water planning based on a more accurate knowledge of how much water is available. Economic and engineering research into supplemental water sources would also increase knowledge of availability.

APPENDIX

APPENDIX A

HYDROLOGIC SUMMARIES OF THE SIX UNITS OF THE CENTRAL UTAH PROJECT

BONNEVILLE UNIT

Hydrology (average annual acre-feet)

Diversion from Uinta Basin to Bonneville Basin	
Present conditions	61,000
Project increase	136,600
Total	197,600
Project water developed in Uinta Basin for local use	27,800
Project water developed in Bonneville Basin for local use	150,000
Project depletion of Colorado River	165,900

Irrigation

	Irrigation water at sources of project supply (average annual acre-feet)			
	Diversion requirement	Water within requirements: Without project	Project increase	Total
Supplemental service land				
Duchesne River area	109,900	80,700	22,800	103,500
Heber-Francis area	63,500	48,100	14,600	62,700
Spanish Fork area	147,000	117,600	22,500	140,100
Peteetneet area	6,100	3,900	1,900	5,800
Mona-Nephi area	30,800	15,200	14,200	29,400
Elberta-Mosida area	10,900	6,600	3,900	10,500
Provo Bay area	8,800	5,500	3,000	8,600
Subtotal	377,000	277,700	82,900	360,600
Full service land				
Spanish Fork area	4,900		4,700	4,700
Peteetneet area	10,200		9,700	9,700
Mona-Nephi area	45,500		43,400	43,400
Elberta-Mosida area	70,700		68,400	68,400
Provo Bay area	21,800		21,300	21,300
Subtotal	153,100		147,500	147,500
Total	530,100	277,700	230,400	508,100

Development periods (years)	3 to 10
Estimated dates for delivery of water	
First delivery	
Unita Basin	1968
Bonneville Basin	1972
Delivery to all project lands	1980

BONNEVILLE UNIT (Cont.)	acre feet
Municipal and Industrial Water	
Average annual water supply (acre-feet)	
Springville to Nephi	9,000
Provo to Salt Lake City	
Utah County	20,000
Salt Lake County	50,000
Total	79,000
Average annual payments by municipal and industrial water users	
Per acre-foot of project supply	$6.15
Total	$2,065,000
Estimated dates for delivery of water	
First delivery	1972
Delivery of all municipal and industrial water	1980
Power	
Installed capacity (kw.)	133,500
Average salable capacity at delivery points (kw.)	108,800
Average annual energy generation at power plants (k,000 kw-hrs.)	
Pumping energy	27,700
Commercial energy	291,800
Total	319,500
Average annual salable energy at delivery points (1,000 kw-hrs.)	271,400
Average annual project power revenues	$2,479,000
Estimated dates for generation of project power	
Initial generation	1974
Full generation	1975

JENSEN UNIT

Project increases in supply	
Irrigation	4,700
Municipal use	10,800
Industrial use	7,200
Total	22,700
Depletion of Colorado River	15,000

Irrigation Service Area (acres)

Full Service land	440
Supplemental Service land	3,640
Total	4,080

UINTAH UNIT

Water Supply

	acre feet
Irrigation water at canal heads	
Storage supply	42,700
Savings of canal losses	4,700
Return flow	4,600
Total	52,000
Municipal and industrial water	1,000
Depletion of Colorado River	30,500

Irrigation Service Area (acres)	Water right acreage	Land ownerships
Supplemental service lands		
Indian	34,152	25,152
Non-Indian	11,000	20,000
Sub-total	45,152	45,152
Full service lands		
Indian	7,818	7,818
Total	52,970	52,970

VERNAL UNIT

Water Supply

	acre feet
Irrigation supply	31,683
Municipal water supply	1,600
Annual average estimated water supply for irrigation as determined over the study period 1929-1956	17,900

UPALCO UNIT

Water Supply

Project water supply at canal heads	
Storage supply	4,300
Savings of canal losses	1,700
Total	20,500
Depletion of Colorado River	10,300

Irrigation Service Area (acres)	Water right acreages	Land ownerships
Supplemental service land		
Non-Indian	27,540	33,610
Indian	15,070	9,000
Total	42,610	42,610

UTE INDIAN UNIT

Water Supply	acre feet
Municipal and Industrial Use	
Uintah Basin	136,000
Bonneville Basin	315,000
Subtotal	451,000
Irrigation	
Uintah Basin	
Indian lands	143,000
Non-Indian lands	68,000
Bonneville Basin	
Non-Indian lands	75,000
Subtotal	286,000
Total Project Water	737,000
Depletion of Colorado River	480,000

Irrigation Service Area	acres
Uintah Basin	
Indian land (full service)	29,118
Indian land (supplemental service)	49,222
Non-Indian land (supplemental service)	52,700
Subtotal	131,040
Bonneville Basin	
Non-Indian (supplemental service)	100,000
Non-Indian (full service)	14,300
Subtotal	114,300
Total	245,340